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Research paper

Zones of influence for railway traffic ground-borne vibrations

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Abstract: The article presents selected results of the assessment of the harmfulness of building vibrations and the impact of railway traffic on people staying in buildings. The research presented in the article concerns a long-term field study. Field research was conducted in various locations and with the movement of various types of rolling stock. The results were the basis for determining the zones of influence of railway vibrations on the building structure. The criteria adopted in the research were the conditions of the impact of vibrations on the structure of buildings as well as the vibration comfort for people staying in buildings and passively perceiving vibrations. The paper presents the methodology of field research and selected results from the conducted research. The proposed zones vary depending on the type of trains (freight and passenger). The range of zones also depends on the structure of the building and human perception of passively perceived vibrations. All analyses carried out for the purposes of this work are in accordance with Polish regulations and were performed by an accredited laboratory for testing vibrations and deformations of buildings. The proposed zones were adopted for use in design and diagnostic practice regarding the impact of vibrations on buildings and people in buildings.

Keywords: building, influence on humans, long-term measurements, railway-induced vibrations, vibration comfort, zones of influence

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1. Introduction

The motivation for the attempt to determine the appropriate distances (zones), beyond which there are no negative impacts of communication traffic on the buildings and people staying in them, was the research dealing with earthquakes and induced seismicity [1–3]. Providing comfort for people staying in buildings is a crucial problem to be solved when designing new facilities, not only in earthquake areas but also due to traffic-induced movement. In some cases, this may be an essential design criterion. The undertaking of such works also results from the entries in projects that must meet the requirements of state regulations. An additional motivation is the lack of articles in the literature dealing with the issue related to determining the zones of the negative influence of the impact of traffic-induced vibrations on buildings and people staying in them.

Ground traffic is a potential hazard to occupants and buildings. It's important to minimize any potential hazards that may arise due to dynamic influences. One way to do this is by ensuring that buildings are located at proper distances from roads and railways. Rapid economic development of countries increases demand for new areas suitable for housing and office space, which are increasingly close to roads and railways. It's important to take this into account when planning and designing new developments. These are areas that, due to their location, are attractive to investors and developers.

Some papers concerned the influence of traffic-induced vibrations on buildings [4–9]. The authors obtained a satisfactory approximation of the dynamic response of buildings to traffic load assuming a rigid building supported on soft soil. Otherwise, structural damage to the building's load-bearing walls may occur as cracks. Proposed solutions in [10–14] in the way of road repairs, limit traffic, barriers in-ground, damping trench and a row of piles lead to limiting destruction in buildings and occupants protection. The solutions for restricting the level of tram-induced and railway-induced vibrations for buildings and bridges, respectively, have also been reported and proposed in [15, 16]. In turn, article [17] refers to the validation of a numerical model for the prediction of vibrations in buildings excited by rail traffic in tunnels.

The studies of transport origin vibrations also concern their impact on heritage buildings [10, 18, 19].

Computer methods such as FEM can be quite useful in supporting the modeling of structures, analyzing wave propagation in the subsoil of elements, and responding to kinematic loadings [5, 20].

At present traffic, influence is increasingly becoming more challenging as the problem inevitably occurs in more populated areas, and this is the issue closer to people and structures. This problem requires designing to ensure that traffic-induced vibrations are safe for buildings and people. We can determine the influence zones of transport-induced vibrations depending on the source of vibrations and distance from the source of vibrations if we dispose of several reliable measurement databases. Our research implements this approach.

Actual Polish standards [21, 22], instructions and law act [23, 24], clearly indicate an obligation to design structures near railroad routes and roads considering the dynamic effects. Vibration monitoring measurements are helpful in assessing the impact of vibrations [25].

On the other hand, the DIN standard [26] also divides vibration acting on structures as ad hoc and long-term. The DIN standard [26] lists guideline values for evaluating vibration on buried pipework and floors. The authors of the paper [27] present permissible limits of vibration in the case of vertical vibrations generated by passages of the metro train during rail operation that significantly affect nearby different building structures (e.g. monuments, hospitals, and concert halls). Particular construction characteristics of the buildings have an impact on the diffusion of vibration inside the buildings. This influence is the basis for the division of buildings in standards [22, 26] for assessing the impact of vibrations on their structures.

The article presents empirical test results for ballast surfaces in various locations, considering different types of rolling stock. However, the article does not distinguish between zones based on the type or lack of vibration isolation used. The defined zones are purely empirical. To take into account the type and structure of vibration isolation, individual analyses and tests, including laboratory tests of vibration isolation solutions, may be necessary. Previous works (references [28–32]) have analysed the impact of different railway construction solutions on the level of vibrations transmitted to the surroundings of the railway line.

The article shows the importance of including dynamic effects at the beginning of the design process, by presenting and analysing the long-term in-situ tests. The following novelty of the paper could be listed:

– Determination of vibration impact zones of origin in railway traffic in Poland depending on the types of trains and buildings construction, separately for the buildings and residents using full-scale multiple long-term ground-borne and dozens of buildings vibrations.
– Introduction of WODB and WODL indexes [21, 22] to assess the impact of vibrations on buildings and residents and to determine the zones of vibration impact on buildings and humans.
– Separate zones of the impact of vibrations have been proposed taking account of the reception of vibrations by buildings and residents.

The article presents the results of in-situ tests and their analysis from the passages of various types of trains in Poland. In Poland, reconstruction and modernization of many railway routes are currently underway, the purpose of which is to increase the operational speed of trains. The results of our studies conducted in Poland can also be used in other countries where modernization works of railway routes are or will be carried out. The research methodology presented in the article can be treated as common in studies conducted by other researchers in similar conditions.

2. SWD scales, WODB and WODL indexes

The Polish standard [22] proposes two methods for assessing the impact of vibrations transmitted through the soil on the buildings:

– the traditional way of dynamic analysis using the FEM model of a building structure,
– or a simplified assessment of selected building types using SWD scales (in English: DIS – Dynamic Influence Scale).

SWD scales are limited to buildings made of masonry elements (i.e. elements intended for manual stacking) and structures made of prefabricated elements (a large block, a large slab). There are two types of SWD scales used (SWD-I and SWD-II) depending on the features of the building [22].

Using the SWD scales, time traces of horizontal vibrations (in the x and y directions) are recorded in a rigid node of the structure on the foundation of the building, or the basement wall at the ground level and from the vibration source side. They are analysed in 1/3 octave bands, obtaining in each of the groups the maximum (peak) values of acceleration (velocity) of vibrations.

The standard [22] introduces the WODB index to measure the vibration perception by a building structure [24] and calculated using relation (2.1):

$$\text{WODB} = \max\left(\frac{a_{\text{Peak}}}{a_A}\right) \tag{2.1}$$

where:

a_{Peak} – peak value of acceleration (for the vibration of building foundation or basement in two horizontal directions) obtained from analysis in 1/3 octave band,

a_A – acceleration value equivalent to the threshold for the perception by the building of horizontal vibration (line A in SWD scale) in the same 1/3 octave band.

According to the Polish standard [21] based on provisions of the standard ISO [33], the primary method of assessing the impact of vibrations on people is using the RMS value of the vibration acceleration in 1/3-octave bands. The calculated RMS values using the acceleration vibration records measured in place of human vibration reception are the base for further assessment. The ISO standard [33] introduced the weighting of the vertical z and horizontal components x and y of the vibration acceleration in 1/3 octave bands. The weighting factors differ depending on the direction of the analysed vibrations. The standard [21] provides the RMS values of the vibration acceleration in 1/3-octave bands corresponding to the threshold of perception of human vibrations. In the assessment of the impact of vibrations on people, the standard [21] uses a coefficient that takes into account the impact of the nature and repeatability of vibrations on the required vibration comfort. In the analysis purpose of the room and the time of day when people in the building are exposed to vibrations are conducted.

Comparison of the RMS values with the value corresponding to the threshold of human vibration perception and the level allowed for providing the required comfort to humans permits us to assess the negative influence on the human body.

The WODL index [21, 25] is the measure of vibration perception by people calculated using relation (2.2):

$$\text{WODL} = \max\left(\frac{a_{\text{RMS}}}{a_1}\right) \tag{2.2}$$

where:

a_{RMS} – acceleration RMS value obtained from analysis in 1/3 octave band;

a_1 – horizontal or vertical acceleration RMS value equivalent to the threshold for the perception by humans of vibration in a horizontal or vertical direction in the same 1/3 octave band as in a_{RMS}.

Values of WODB and WODL indexes should be given together with the corresponding values of the centre frequency of the 1/3 octave band.

The article shows the importance of including dynamic effects at the beginning of the design process, by presenting and analysing the seriousness of in-situ tests. The main goal was to define zones considering impacts on buildings and people staying in them independently for passenger traffic, freight traffic (cargo traffic) and mixed traffic, which was the effect of in-situ measurements.

3. Research fields

The research results presented in the article and the zones determined on their basis were developed based on research in 24 locations throughout Poland. Joining, nearly 1000 vibration registrations were analysed. The objects selected for analysis were located at a distance of 3 to 90 m from the railway line. All tests were performed by an accredited laboratory.

3.1. Characteristics of the example examined buildings and distances of the buildings from the railway line

The measurements of building vibrations we performed in two stages (ad hoc and long-term measurements). The distances from buildings to the source of excitation (nearest track) remain in the range of 21.3 to 67 m. The goal of the research was to assess the impact of vibrations on structures and people staying at the buildings.

The research refers to 24-hour in-situ measurements in 24 selected reference buildings in 24 locations in Poland located at railway lines with traditional track structures both before and after their modernisation. "After modernisation" may concern: a change of track-bed, construction of rails or introduction of vibroinsulation. Distances of the examined buildings from the railway lines ranged from 3 to 89 meters (Table 1). The dimensions, construction and materials qualified the buildings to the scale SWD-I and SWD-II.

The measurements included the recording of accelerations and vibration frequencies at selected measuring points located in the buildings. Using these records, we assess the impact of vibrations on buildings and people staying in them for two representative buildings in two selected locations (location No. 1 and location No. 2). The train velocities considered during the analysis were operational speeds of up to 200 km/h. Additionally, it's worth noting that all the surfaces analysed were ballast surfaces. Table 2 shows a detailed description of two example buildings and their location relative to tracks. In location No. 1, the rails rest on pre-stressed concrete sleepers spread on a ballast.

4. Research methods

The research of four and twenty-four selected reference buildings included ad hoc and 24-hour measurements of accelerations and vibration frequencies at selected measuring points located in the structures, respectively. The results of the study determine the impact of vibrations on the buildings. They let them calculate the magnitude of dynamic influences on people in

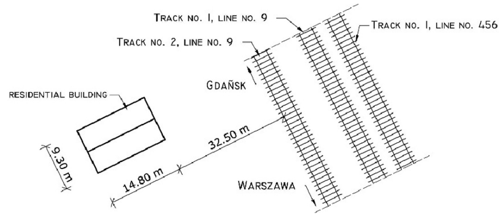
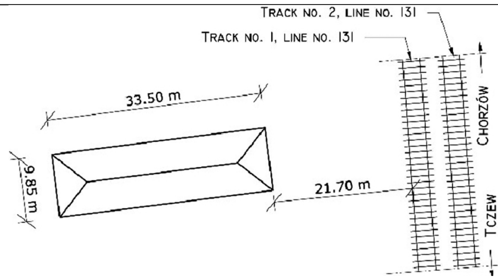
Table 1. Distances and types of buildings

Localisation	**Distance from near track to building, [m]**	**Type of the building**
1	3.00	Railway infrastructure buildings
2	11.00	
3	15.30	
4	18.50	Residential buildings
5	21.00	
6	22.00	
7	25.00	
8	26.70	
9	28.70	
10	29.20	
11	30.00	
12	31.10	
13	32.05	
14	33.70	
15	35.50	
16	36.50	
17	37.70	
18	40.00	
19	40.00	
20	42.50	
21	47.60	
22	59.00	
23	67.00	
24	89.00	

the tested structures. Three orthogonal directions: two horizontally perpendicular x and y, and vertical z-direction are included in each time of vibration measurement. The directions x and y were consistent with the axis of the horizontal projection of the building. The direction x was consistent with the direction of vibration propagation (perpendicular to the axis of the railway). The vibrations in the x-direction are called horizontal radial vibrations. Direction y (called horizontal transversal vibration) was parallel to the axis of the railway line. Measurement sensors recorded the accelerations of vibrations caused by the passage of individual trains. In each location, we performed several hundred such registrations. These records were then subjected to analysis to assess the impact of vibrations on the building and humans in the building, following Polish standards [21, 22].

SWD scale diagrams and the values of the WODB ratio presented in the Polish standard [22] show the results of the impact analysis vibrations on the building.

Table 2. Description of two example buildings examined during 24-hour tests in Location No. 1 and Location No. 2

<table>
<tr><th colspan="4">Building's general view and location relative to tracks (location 1)</th></tr>
<tr><td></td><td colspan="3">
</td></tr>
<tr><td>Dimensions in-plane, m</td><td>Number of storeys/bearing system</td><td>Source of vibrations</td><td>Distance from near track to building, m</td></tr>
<tr><td>9.3 × 10.95</td><td>1 + attic/masonry walls</td><td>Freight (cargo) and passenger trains</td><td>32.5</td></tr>
<tr><th colspan="4">Building's general view and location relative to tracks (location 2)</th></tr>
<tr><td></td><td colspan="3">
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The results of the analysis of the impact of vibrations on people in the buildings were presented further on in the form of bar graphs with maximum useful values of RMS (root mean square) vibration accelerations at the place of their reception by people defined in the 1/3 frequency bands [21] and the lines corresponding to the threshold of human vibration perception and the level allowed for providing the required comfort to humans. The continuous lines correspond to vibrations in the direction parallel to the axis of the spine and the dashed lines – are vibrations perpendicular to the axis of the spine. In order from the lowest, these lines represent:

- a threshold of perceived vibration by people,
- an upper level of providing comfort during the night time (from 10 pm to 6 am),
- a high level of comfort during the daytime (from 6 am to 10 pm).

During the 24-hour measurements performed on in-situ buildings, kinematic excitations varied taking into account: the moving trains, the speed of the passage and the construction of the track. The analysis of the results separately refers to the impact of vibrations generated on buildings and humans. The study also includes various types of trains: Pendolino trains, Long-distance trains, PESA long-distance trains, Suburban trains – new model, Suburban trains – old class, railcars, freight (cargo) trains, special trains, trolleys, single locomotives.

In all of the locations, the study included measurements of accelerations in control points of the analysed buildings. Control points we installed according to Polish standards [21, 22]. In all cases in each control point, accelerations were measured in three orthogonal directions using specialised apparatus [32]. The instrumentation system and control equipment consisted of accelerometers, strain gauges, a four-channel amplifier, a 16-channel recorder, an oscilloscope, and a PC with specialised software to analyse the data records. The instrumental system consisted of PCB 393B12 accelerometers and a digital analyser LMS Mobile Scadas equipped with an analogue low-pass Butterworth filter of 0–100 Hz. The above-mentioned apparatus was designed to measure the low-frequency vibrations that occurred in the examined cases. The linearity deviation of the PCB sensor signal does not exceed 2.3%. The relative standard uncertainty of the maximum acceleration signal resulting from installation errors, instrumental system, and analysis does not exceed ±11.61%. In both locations, measurements lasted 24 hours. The realisation of several hundred measurements was in location 1 due to the heavy load of the line. The second place for almost one hundred measurements was in location 2. The records from locations 1 and 2. we analysed according to [21, 22], to set the influence on building structures and human perception. We used acceleration records from these points (in three orthogonal directions) to estimate the influence of vibrations on the building according to [22]. We located the measurement points on the central place of the floor where vertical vibrations are the greatest. We also measured free-field acceleration starting from the railway track to a distance of 50 m. The distance of the measuring points was every 5 m to establish the attenuation dependence of free-field vibrations. During the research, we simultaneously recorded acceleration, and speed and identified the type of trains.

5. Results and discussion

5.1. Analysing the distance of the building from the railway line

Vibrations caused by thirteen train passages out of 357 before modernisation were harmful due to the influence on the buildings (WODB $>$ 1) located within 35 meters of the railway track. After line modernisation, vibrations originating from 3 of 596 train passages were harmful to buildings located within 20 meters of the railway track. Fig. 1 and 3 show example acceleration (horizontal component) records measured at selected locations for different distances from the railway line to the nearest buildings. Fig. 2 and 4 present the corresponding vibration spectra in one-third octave bands. The red line in Figures 2 and 4 represents the threshold of vibration that the building can detect, while the black lines indicate the limits of the impact of vibrations on the building structure by the standard [22]. In these figures, the WODB index values are presented along with the exemplary analysis results for the most intensive waveforms at various distances from the railway line. The presented results analysis suggests that the sensitivity limit of the building is exceeded for buildings located within a distance of up to 35 meters from the railway line. Based on a comprehensive analysis of the measurement material collected at 24 different locations, the range of impact zones of railway vibrations on buildings was determined.

Analysing the impact of the distance of the railway from the structure due to the influence on people staying in the analysed buildings we noticed that out of 357 train passages before modernisation, in 160 cases the WODL index was higher than 1 (44.8%). When the value is equal to 1, it indicates that the threshold of vibration perception by humans has been reached. After modernisation for 596 train passages on lines in 85 instances, the WODL index was higher than one (14.3%). It means that modernisation fulfils the goal. Fig. 5 and 7 show example acceleration (vertical component) diagrams recorded during measurements for selected locations, differently distanced from the railway line to the nearest building points. In contrast, Fig. 6 and 8 present RMS spectra in one-third octave frequency corresponding to records from Fig. 5 and 7. As shown in Figures 6 and 8, the red dashed and solid lines represent the thresholds of vibration perception by individuals in the horizontal x and y directions, as well as the vertical direction, respectively. Meanwhile, the black lines indicate the vibration comfort limit, which varies depending on the room's intended use and the time of day, as specified by the standard [21].

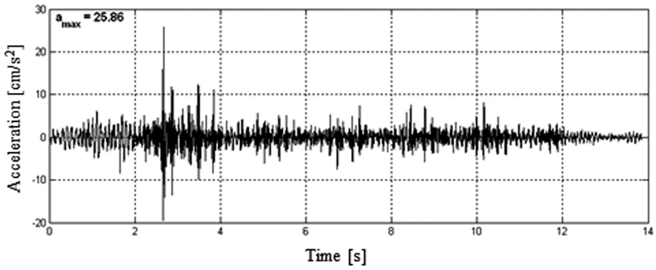

Fig. 1. Acceleration diagram; building distanced 5 m from the railway line; freight (cargo) train

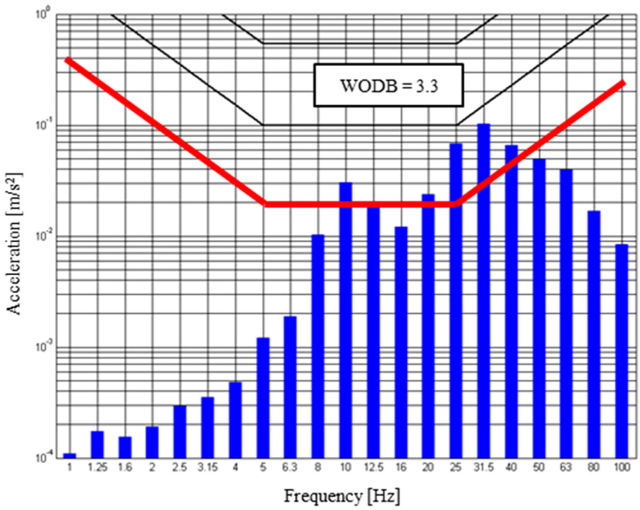

Fig. 2. Vibration spectrum in one-third octave frequency; structure distanced 5 m from the railway line; freight (cargo) train (I zone of the SWD scale – below the red line)

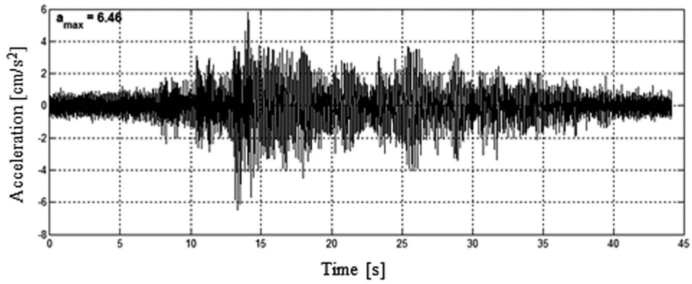

Fig. 3. Acceleration diagram; building distanced 30 m from the railway line; freight (cargo) train

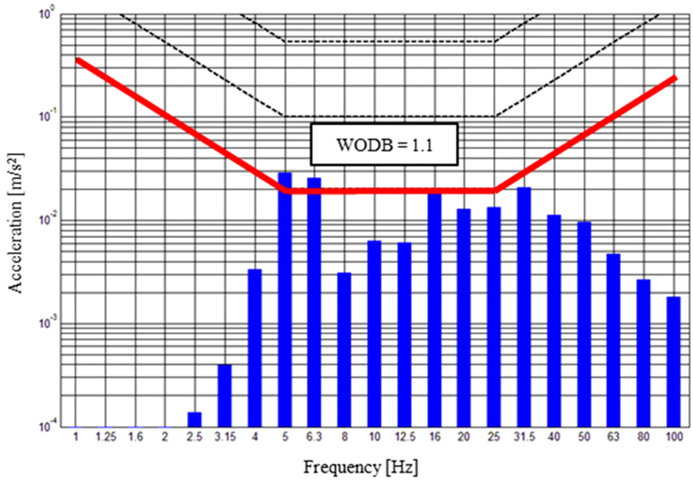

Fig. 4. Vibration spectrum in one-third octave frequency; building distanced 30 m from the railway line; freight (cargo) train (I zone of the SWD scale – below the red line)

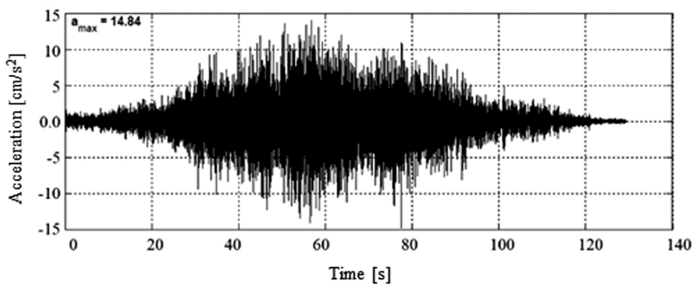

Fig. 5. Acceleration diagram; building distanced 47 m from the railway line; freight (cargo) train

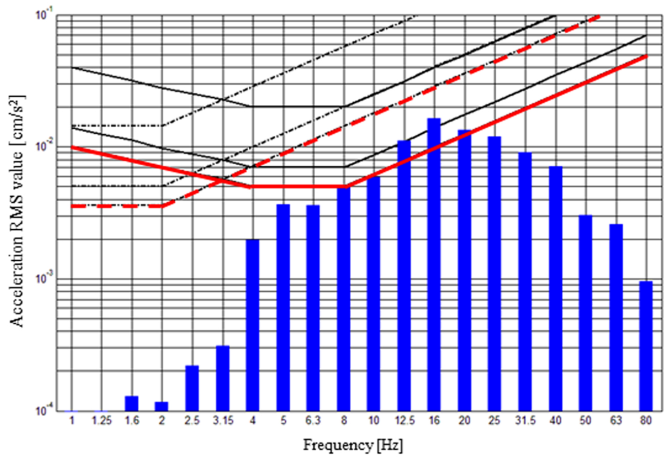

Fig. 6. RMS spectrum in one-third octave frequency; building distanced 47 m from the railway line; freight (cargo) train

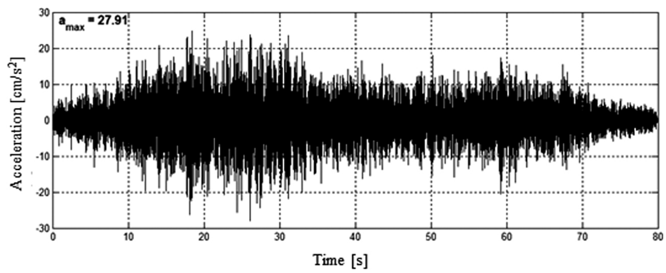

Fig. 7. Acceleration diagram; building distanced 67 m from the railway line; freight (cargo) train

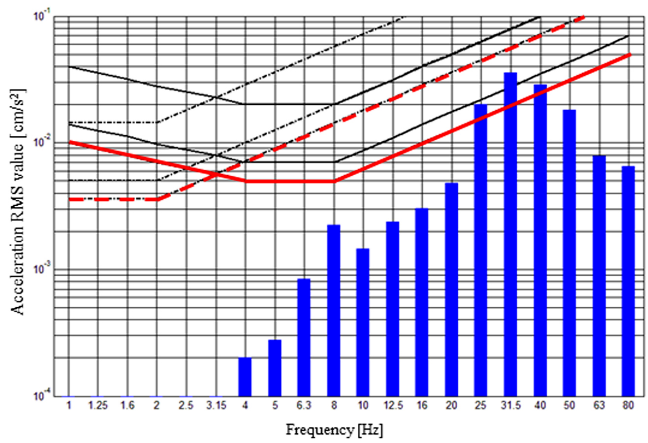

Fig. 8. RMS spectrum in one-third octave frequency; building distanced 67 m from the railway line; freight (cargo) train

5.2. Analysing a wide variety of trains and their velocities

Analysing the influence of different types of trains running at different velocities, according to 24-hour measurements in location 1 and location 2 are presented in Figs. 9 and 10. Fig. 11 and 12 present some chosen representative RMS spectra in one-third octave frequencies. These figures correspond to different types of trains, and velocities. Figures 13 and 14 present the dependence of the WODL index on the velocity of trains.

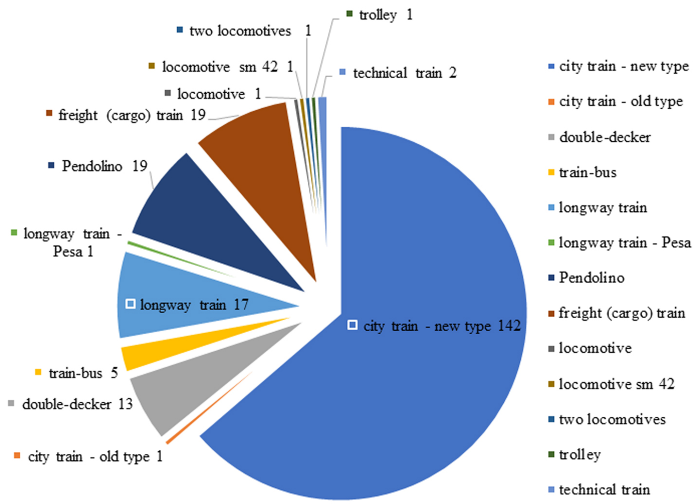

Fig. 9. Different kinds of train passages – 24-hour measurements – location 1

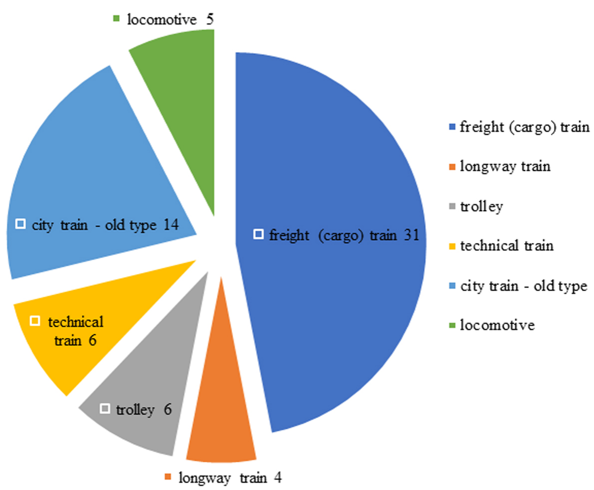

Fig. 10. Different kinds of train passages – 24-hour measurements – location 2

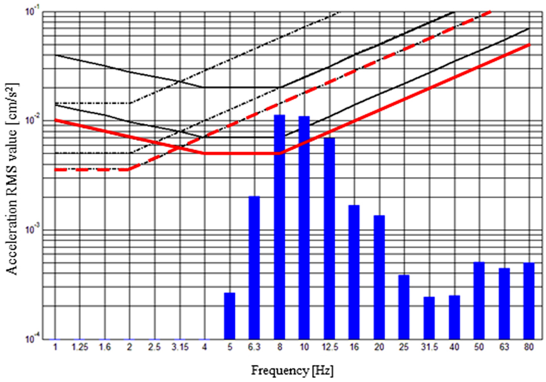

Fig. 11. RMS spectrum in one-third octave frequency; location 1; freight (cargo) train, v = 110 km/h

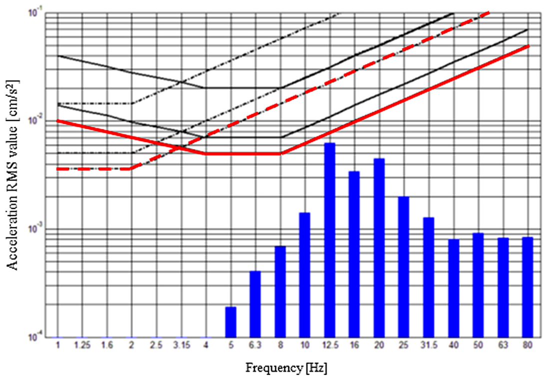

Fig. 12. RMS spectrum in one-third octave frequency; location 1; Pendolino, v = 156 km/h

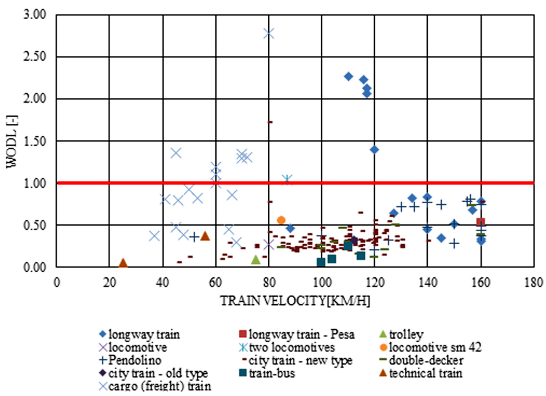

Fig. 13. WODL in location 1 – 24-hour in-situ study measurements

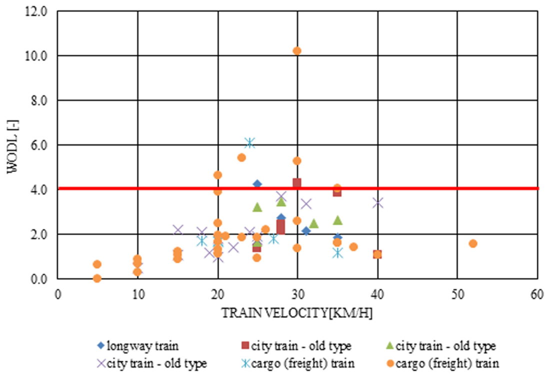

Fig. 14. WODL in location 2 – 24-hour in-situ measurements

5.3. Discussion of the results

Using the research results referring to impact vibrations on people, we have found that the limit distance of their perceived effect is 65 m, regardless of whether railway traffic took place on lines before or after modernisation. The research does not show any generalised relationship between the speed of passage of different rolling stocks and the occurrence of excessive vibrations both on buildings and on people. This result may be due to the type of rolling stock (e.g. freight trains, long-distance trains, Pendolino trains, suburban trains) has a decisive influence on the vibration emission, its technical condition (especially the state of the wheels) and the mechanical condition of the railway line (contact rails or non-contact rails, type of sleepers), a technical term of the rails. Such conclusions come to mind after thoroughly analysing location No. 1 and location No. 2 in the long-term measurements.

By far the most significant impact of vibrations on buildings and people in buildings occurs during the passage of freight trains. Another essential source of the dynamic effects is long-distance train passages in the velocity range of 100–120 km/h. On the other hand, the tests that took place during the test passages, and the regular Pendolino trains, do not show that these passages generate a higher level of vibration than long-distance trains (at the same speed they were slightly lower). Comparable or smaller values of the WODL index give vibrations generated by suburban trains (of all types) as well as rail cars, as long as their technical condition does not diverge from the average. Analysis of received results shows that in locations No. 1 and No.2, the WODB index did not exceed the critical value equal to 1. It means that in the case of all analysed vibrations, none of them was perceptible by building construction.

Calculated RMS values based on measured acceleration records in the 1/3 octave band show exceeding human comfort according to the Polish standard [21]. In the first location out of 223 train passages in 14 cases, RMS values exceed the critical value of the WODL index. The last result refers mainly to freight (cargo) trains. Tables 3 and 4 show selected measurements of different types of trains with significant values of WODL respectively to locations 1 and 2. These tables contain the values of the WODL index and correspond to the central frequency of the 1/3 octave band. For the second location, 57 of the recorded 66 train passages exceed the critical value of the WODL index. A large number of records with WODL greater than 1.0 is caused mainly by freight (cargo) trains. A large number of files with WODL greater than 1.0 is created primarily for freight (cargo) trains. The wooden ceiling is much more flexible than the concrete slab from the first location primarily resulting in large values of WODL.

Table 3. Collective results of the human vibration perceptivity index from location No. 1

No.	**Type of train**	***v* [km/h]**	**WODL [–]**	**The central frequency of 1/3 octave band [Hz]**
1	**2**	**3**	**4**	**5**
1	freight (cargo) train	37–80	0.30–2.78	5.0–20.0
2	City train – a new type	46–160	0.06–1.71	6.3–50.0
3	City train – old type	112	0.32	8.0–10.0
4	double-decker	85–160	0.12–0.73	5.0–50.0
5	locomotive	80	0.28	8.0–16.0
6	locomotive sm 42	85	0.56	10.0–20.0
7	long way train	88–160	0.31–2.26	6.3–20.0
8	Long way train – Pesa	160	0.53	8.0–20.0
9	Pendolino	52–160	0.21–0.80	5.0–50.0
10	technical train	25–56	0.05–0.38	8.0–25.0
11	train-bus	100–115	0.06–0.25	8.0–16.0
12	trolley	75	0.1	8.0–20.0
13	two locomotives	87	1.04	8.0–8.0

Based on the analysis of the results, two dynamic zones are proposed considering impacts on buildings and people staying in them. The zones are constructed independently for passenger, freight (cargo) and mixed traffic (Table 5). When analysing traffic vibration emissions, the WODL indicator holds the most significance. However, based on the analysis of the WODB index value, it can be concluded that while identifying vibration impact zones on buildings, it is essential to differentiate between the vibrations caused by passenger and freight trains. This differentiation of vibrations formed the basis for distinguishing the zones Ia and Ib. Table 5 shows the proposed zones that range from one to another, depending on the kind of trains.

In contrast, the set of boundaries for zone II (IIa and IIb) concerns the vibration influence on humans. The train type significantly affects the generated vibrations. The WODL values increase significantly and differ in the group of particular kinds of trains. It may indicate a bad technical condition of the train. The level of vibrations generated by train passages can be used in the future for monitoring the Longway condition of trains similarly as is done in Metro [25].

Table 4. Collective results of the human vibration perceptivity index from location No. 2

No.	**Type of train**	***v* [km/h]**	**WODL [–]**	**The central frequency of 1/3 octave band [Hz]**
1	**2**	**3**	**4**	**5**
1	freight (cargo) train	10–35	0.51–6.12	12.5–20.0
2	City train – old type	24–40	1.09–4.31	12.5–20.0
3	locomotive	23–35	0.93–10.20	12.5–20.0
4	long way train	25–35	1.87–4.24	12.5–20.0
5	technical train	5–35	0.66–4.05	16.0–20.0
6	trolley	10–52	0.31–1.84	12.5–20.0

Table 5. Zones of influence on buildings and humans

Train type	**The distance of the building from the axis of the outer track**	
	Influence on buildings	**Influence on the human body**
Passenger trains	up to 35 m (zone Ia)	up to 65 m (zone IIa)
Freight (cargo) and mixed trains	up to 45 m (zone Ib)	up to 80 m (zone IIb)

When commenting on the proposed zones regarding buildings, we should supplement them with specific cases referring to the technical state of buildings, construction with contact joints of rails, geometrical and material characteristics of the building, and distance of railway infrastructure facilities from a railway line, the purpose of the building. We emphasise that the above-proposed zones correspond to structures made following engineering rules, with no defective or already damaged structural elements. Subsequently, the proposed influence on human body zones we recommend supplementing with individual cases.

6. Conclusions

The developing infrastructures in Poland near track lines (e.g. motorways, tunnels, modern buildings) were the base for undertaking significant challenges concerning establishing zones for safety. These zones refer separately to buildings and humans living in them. The research was long-time and time-consuming measurements of ground-borne and building vibrations performed in different places in Poland. Different types of trains were the sources of vibrations, e.g. freight (cargo) trains, city trains – new and old models, double-deckers, locomotives, long-way trains, Pendolino, special trains, train buses, and trolleys. The tested buildings were of different types of construction and technical state. Taking into account all the above results the following conclusions could be drawn.

- The research shows that in the case of passenger train passages the influence zone of vibrations on buildings does not exceed 35 m (zone Ia) and is about 30% less than in the case of freight (cargo) and mixed train passages (zone Ib).
- Impact zones for railway traffic vibrations on humans are wider than for buildings. The width of the zone of impact of vibrations from passages of passenger trains does not exceed 65 m (zone IIa). The zone of influence in the case of freight (cargo) and mixed train runs is wider by about 23% and does not exceed 80 m (zone IIb).
- For structures located at a distance that does not exceed 20 m, ruthless verification of the impact of vibrations on buildings and humans is required. Particular care should be taken for buildings for particular purposes (e.g. hospitals, laboratories, high-rise buildings). In such cases, an individual analysis by an authorized specialist in the field of civil engineering must be performed.
- When determining the range of the vibration impact zones, the influence on people in the buildings is of decisive importance. The range of zones affected by vibrations on people is about twice as large as on building structures and is decisive in designing vibration isolation to reduce the negative impact of vibrations.

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Strefy wpływów dynamicznych od ruchu kolejowego

Słowa kluczowe: budynek, komfort drgań, strefy oddziaływania, wpływ na ludzi, pomiary długoterminowe, drgania wywołane przez kolej

Streszczenie:

W artykule przedstawiono wybrane wyniki oceny szkodliwości wpływu drgań od ruchu kolejowego na budynki oraz na ludzi przebywających w budynkach. Badania przedstawione w artykule dotyczą długoterminowych badań terenowych. Badania terenowe przeprowadzono w różnych lokalizacjach i przy ruchu zróżnicowanego taboru kolejowego. Wyniki stanowiły podstawę do określenia stref oddziaływań drgań kolejowych. Kryteriami przyjętymi w badaniach były warunki oddziaływania drgań na konstrukcje budynków oraz warunki komfortu drgań dla ludzi przebywających w budynkach i biernie odbierających drgania. W artykule przedstawiono metodykę badań terenowych oraz wybrane wyniki przeprowadzonych badań. Proponowane strefy różnią się w zależności od rodzaju pociągów (towarowe i pasażerskie). Zasięg stref zależy również od konstrukcji budynku i percepcji człowieka biernie odbierającego drgania. Wszystkie analizy wykonane na potrzeby niniejszej pracy są zgodne z polskimi przepisami i zostały wykonane przez akredytowane laboratorium do badań drgań i odkształceń budynków. Zaproponowane strefy zostały przyjęte do stosowania w praktyce projektowej i diagnostycznej dotyczącej wpływu drgań na budynki i ludzi w budynkach.

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