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Research paper

Influence of vehicle speed on the vibration comfort of occupants in a residential building

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Abstract: The paper analyses the influence of passenger car speed on the vibration comfort of occupants in a residential building located along a local road with a speed bump. A series of in-situ measurements was carried out for repeated vehicle passages at controlled speeds ranging from 20 to 44 km/h. Floor accelerations were recorded in several measurement points representing different storeys and room functions. For each passage, frequency-weighted RMS acceleration indices were determined in accordance with the Polish standard PN-B-02171:2017 and compared with comfort criteria for residential use. The results reveal a clear spatial variability of vibration perception within the building, as well as a non-linear relationship between vehicle speed and comfort indices. In some locations even low and medium speeds (around 20–30 km/h) lead to values close to the admissible limits, whereas further increases in speed do not always result in a proportional growth of vibration indices due to the dynamic properties of the building–soil–vehicle system and the excitation by the speed bump. The findings emphasise that, for residential buildings located near traffic calming devices, speed management should be combined with vibroacoustic assessment and design to ensure acceptable vibration comfort for occupants.

Keywords: frequency-weighted RMS acceleration, PN-B-02171:2017, speed bump, traffic-induced vibrations, vehicle speed, vibration comfort of occupants

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1. Introduction

Road traffic is one of the most widespread sources of environmental vibrations in urban and suburban areas. In addition to commonly discussed issues such as air pollution and traffic noise, vehicle-induced vibrations may significantly affect both the structural response of nearby buildings and the comfort of their occupants. This concerns not only buildings located in the vicinity of major roads or railway lines, but also low-rise residential structures situated along local streets equipped with traffic calming devices, where the excitation is highly localised and repetitive. In such conditions, even relatively low vibration levels, far below thresholds for structural damage, can be perceived as annoying or disturbing by the occupants and may influence their quality of life and sense of safety.

Human exposure to transport-Induced vibration can be considered in three basic situations: active, when a person drives a vehicle [1]; quasi–active, when a person is a passenger in a means of transport [2]; and passive, when a person is staying in a building subjected to vibrations transmitted from the surroundings [3]. The beginnings of quantitative criteria for assessing the perceptibility of vibrations by humans date back to the 1930s, when the Reiher-Meister reference scale was introduced [4]. This scale used displacement within a frequency range of 1–100 Hz as the assessment criterion. However, its main weakness is the lack of a precise definition of qualitative descriptors such as "annoying" or "unpleasant" and the distinction between them. As a result, such vaguely formulated criteria turned out to be of limited practical use in civil engineering applications. To overcome this limitation, Wiss and Parmelee [5] proposed an empirical relationship between floor vibration levels and response ratings, defining five vibration perception categories ranging from 1 (imperceptible) to 5 (comfortless). A major step forward was the publication of the first edition of the ISO standard on human exposure to whole-body vibrations in 1974, which summarised the state of knowledge up to that time, as comprehensively reviewed by Cowley [6]. Following the work of Irwin [7], ISO 2631 [8] was revised and reissued in 1985. Irwin introduced a baseline curve for general whole-body vertical vibrations and corresponding weighting factors that depend on the time of day (or night), the type of building usage (residential, office, workshop, etc.) and the vibration character (continuous, intermittent or impulsive). The 1985 version of ISO 2631 has since become the basis for many national standards.

In the field of human perception of vibrations, it is important to distinguish between active and passive exposure [9]. When occupants perceive vibrations in buildings, this may affect their well-being, productivity or working efficiency [10]. At the same time, it is well known that people tolerate much higher vibration levels in vehicles than in buildings. This difference stems from the distinct frequency ranges involved: the dominant frequencies of vibrations transmitted to building occupants lie in the low-frequency range, close to the natural frequencies of internal organs and the human body as a whole [10]. For this reason, active (e.g. vehicle drivers and passengers) and passive (building occupants) perception of vibrations should be treated separately when formulating comfort criteria.

Occupants are capable of detecting building vibration levels that are well below those associated with any risk of structural damage. In other words, the limit for human comfort is significantly lower than the limit for building safety. As a consequence, contemporary design and diagnostics related to environmental vibrations are primarily governed by human perception rather than by structural damage considerations [11]. This shift in focus is reflected in modern standards, which typically express vibration criteria in terms of frequency-weighted acceleration measures and provide comfort limit values for various room types and occupancies.

In the context of road transport, vibrations are generated mainly by the interaction between moving vehicles and surface irregularities such as joints, potholes, patch repairs and traffic calming devices [12]. Speed bumps, widely used to reduce vehicle speeds and improve traffic safety, represent a special case: they introduce short-duration, relatively intensive dynamic loads that can propagate through the soil and foundation system to the floors of nearby buildings [13–15]. The resulting vibration response depends on vehicle mass and suspension characteristics, the geometry of the bump and the dynamic properties of the soil-structure system [16, 17], but it is strongly influenced by the actual driving speed at the obstacle. For residents, changes in local traffic organisation (e.g. installing a speed bump or modifying speed limits) can therefore have a direct and perceptible impact on vibration comfort in living spaces, especially in rooms facing the road.

Although numerous studies have addressed traffic-induced vibrations, much of the literature focuses on heavy vehicles or rail transport, major transportation corridors and large-scale predictive models of soil-structure interaction [18, 19]. Comparatively fewer works deal with low-rise residential buildings along local streets where traffic is dominated by passenger cars and where traffic calming measures are applied [20, 21]. In such settings, the excitation is repetitive but more stochastic in nature, governed by driver behaviour and vehicle speed choices, and the resulting vibration levels may vary considerably between individual rooms and storeys.

In this context, the present study investigates the influence of passenger-car speed on the vibration comfort of occupants in a residential building located along a local road with a speed bump. The analysis is based on in-situ measurements of floor accelerations recorded on different storeys of the building during a series of controlled vehicle passages at various velocities. The acquired signals are processed to obtain frequency-weighted RMS acceleration values and comfort indices in accordance with the relevant standard for evaluating human exposure to vibrations in buildings. The main objective is to quantify how changes in vehicle speed affect vibration comfort in selected residential rooms and to identify speed ranges for which comfort criteria are approached or exceeded. The results provide insight into the transport-related impact on residents and offer guidance for coordinating traffic calming strategies with vibroacoustic requirements in residential building design and assessment.

2. Residential building chosen for analysis

The structure selected for the analysis is a three-storey semi-detached residential building designed as a two-unit system. Each unit has an independent entrance as well as a separate functional and spatial layout. The building forms part of a larger complex of single-family houses located in the suburban area of Kraków County. The facility was constructed in compliance with the local spatial development plan, meeting both urban planning regulations and environmental requirements.

The building has a rectangular form with dimensions of 12.00 × 9.50 m, complemented by architectural projections that serve as compositional accents on the façades. The total height of the structure is 9 m. The building is covered with a symmetrical gable roof inclined at 35°, featuring eaves extending approximately 60 cm beyond the façade line. Dormers have been incorporated into the roof slopes; they continue the geometry of the projections and are finished with flat roofs whose surfaces do not exceed one-third of the main roof area. The architectural expression follows a contemporary aesthetic, emphasized by the horizontal articulation of the façades and the varied texture of the plaster and ceramic cladding. The front façade of the building is presented in Fig. 1.

Fig. 1. Front facade of analysed part of the residential building

The floor plans of the analysed building is presented in Fig. 2. The functional layout of the building comprises the ground floor (Fig. 2a), which constitutes an independent residential unit and includes a living room with a kitchen-ette, three rooms, two bathrooms, and a utility room. The first floor (Fig. 2b) and the usable attic (Fig. 2c) form the second residential unit, accessed via an external open-work staircase. These levels contain living spaces, two bathrooms, a walk-in closet, and an additional room located in the attic. The red frame presented in Fig. 2 highlights the part of the structure (separated by a construction joint) for which the vibration comfort analyses were performed.

The building's load-bearing structure was designed as a masonry-reinforced concrete system. The foundation consists of concrete strip footings and foundation walls made of concrete blocks. The above-grade walls were constructed using perforated ceramic units, and the structural system was further strengthened by concrete columns. The floors are 15-cm-thick monolithic slabs. The roof structure comprises a timber rafter system supported on wall plates and concrete beams, covered with steel sheet roofing. Above the dormers, the roof was executed as a 12-cm-thick concrete slab. The internal staircase connecting the first floor and the attic is of concrete construction, whereas the external staircase consists of prefabricated concrete elements with an openwork configuration.

Fig. 2. Analysed building (a) ground floor; (b) first floor; (c) usable attic

3. Methodology of the experiment

To determine the influence of passenger-car driving velocity on the vibration comfort of building occupants, a series of measurements was carried out in the rooms most exposed to vehicle-induced vibrations. The evaluation of vibration comfort was performed based on the RMS values calculated from the floor acceleration signals generated by the passage of a passenger car over a speed bump (Fig. 3). The speed bump was installed on a local road situated in the immediate vicinity of the analyzed building. The distance between the road edge and the front of building was approximately 10 m. The use of the speed bump enabled an increase of the excitation level. Moreover, it also allowed the test conditions to better represent real operating scenarios typically observed on roads with uneven and partially deteriorated surfaces after several years of service.

Fig. 3. Location of the speed bump in the vicinity of the analyzed building

The measurements of structural vibrations were carried out using a set of accelerometers mounted on a ballast plate, in accordance with the requirements of standard [22]. The PCB 392B12 accelerometers are characterized by a wide frequency range from 0.15 to 1000 Hz and high sensitivity up to 10000 mV/g. The applied measurement system allows recording accelerations in three directions: two horizontal (perpendicular – x and parallel – y to the road axis) and one vertical (z).

To ensure a reliable assessment of the vibration comfort of the building occupants, the measurements were performed in the residential rooms located closest to the vibration source, in this case – the road edge. A set of sensors was installed on the floor slabs of all storeys as well as on the ground-floor slab. To obtain the most unfavourable dynamic response of the floors, the accelerometers were mounted at the mid-span of the rooms. Since the maximum response was expected at the mid-span, one set of sensors placed in this location was sufficient to determine the human comfort parameters. The sensors on the ground floor and the first floor were placed in the same vertical alignment within an end room. Due to the irregular shape of the building, the sensor on the uppermost storey was installed in a room located near the central part of the structure. It should be noted that the distance of all measurement points from the vibration source was comparable, which allowed for a consistent comparison of their dynamic responses. Moreover, the dynamic response of the floors was recorded simultaneously on each floor and in all directions. The layout of the sensors is illustrated in Fig. 4. Additionally, for verification and control of the results, accelerations were also measured at a rigid structural node at the foundation level.

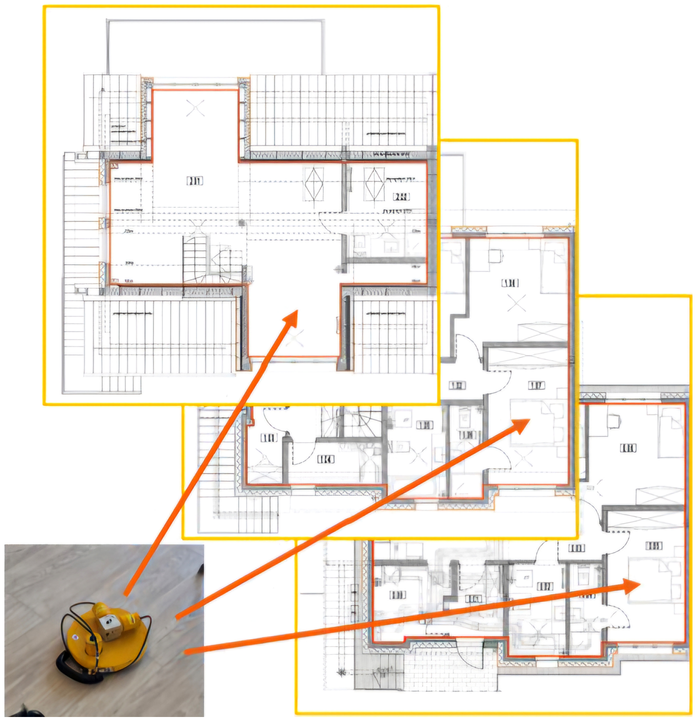

Fig. 4. The sensors layout for measuring accelerations on the different storeys of the building

A passenger car with a mass of approximately 1.8 t was used as the excitation source, driving over the speed bump at various velocities. As part of the experiment, 10 runs were performed, labelled as Test 1–10. In each test, the vehicle velocity ranged from 20 to 44 km/h. The measurement programme assumed three runs over the speed bump at target vehicle speeds of 20, 30 and 40 km/h. Vehicle speed was monitored using the on-board speedometer, and the manuscript reports the actual speeds recorded during each run. Due to the required acceleration distance and transient vehicle motion, especially at the highest target speed, it was not always possible to obtain exactly 40 km/h at the bump. Consequently, within the highest target-speed set, the achieved speeds were 40 km/h (two runs), 43 km/h (one run), and 44 km/h (one run).The selected velocity range reflects the location of the building and the characteristics of the surrounding infrastructure, which includes typical residential roads where vehicles commonly operate at similar speeds. A detailed description of the driving conditions for each test is provided in Table 1.

Table 1. Vehicle speeds during the individual tests

Test no	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
Vechicle velocity	20 km/h	20 km/h	20 km/h	20 km/h	30 km/h	30 km/h	40 km/h	43 km/h	44 km/h	40 km/h

During each test, the floor vibration accelerations were recorded. Subsequently, based on the acquired signals, the RMS values were calculated for each direction in the one third octave bands:

$$a_w = \left[\frac{1}{T}\int_0^T a_w^2(t)\mathrm{d}t\right]^{\frac{1}{2}} \tag{3.1}$$

where: $a_w(t)$ is weighted acceleration as a function of time [m/s^2], T is the duration of measurement [s]

To clarify the results the WODL index was calculated. WODL is an index used in the Polish vibration assessment approach to quantify how much the vibration perceptibility threshold is exceeded in a given direction. It is defined as the ratio of the measured vibration level (typically expressed as the maximum RMS acceleration in the relevant frequency band) to the corresponding reference limit value for human perception. And it can be interpreted as follows:

WODL $\leq$ 1: threshold not exceeded (acceptable)

WODL > 1: threshold exceeded; the value indicates the exceedance factor.

4. Measurement results

4.1. Time histories of measured floor accelerations

Representative time histories of frequency-weighted floor accelerations recorded during the vehicle passages are shown in Fig. 5.

The plots correspond to the vertical component of acceleration measured on the top storey for selected tests with vehicle velocities of 20, 30 and 44 km/h. For all measurement points, the response exhibits a clearly impulsive character associated with the passage of the front and rear axles of the vehicle over the speed bump. This results in one or two dominant peaks of acceleration followed by a rapid decay.

The comparison of time histories between storeys reveals a clear height-dependent amplification of the dynamic response, but with a non-trivial distribution. As expected, the largest vertical accelerations are recorded in the room located on the uppermost storey (usable attic). However, the responses on the ground floor are only slightly smaller than those in the attic, whereas the first floor exhibits the lowest peak values. This pattern indicates a more complex dynamic behaviour of the building, with mode shapes that do not lead to a simple monotonic decrease of vibration levels from top to bottom. In the horizontal directions, the peak accelerations are lower than in the vertical direction and are dominated by the component perpendicular to the road axis, reflecting the propagation path of vibrations from the speed bump towards the building.

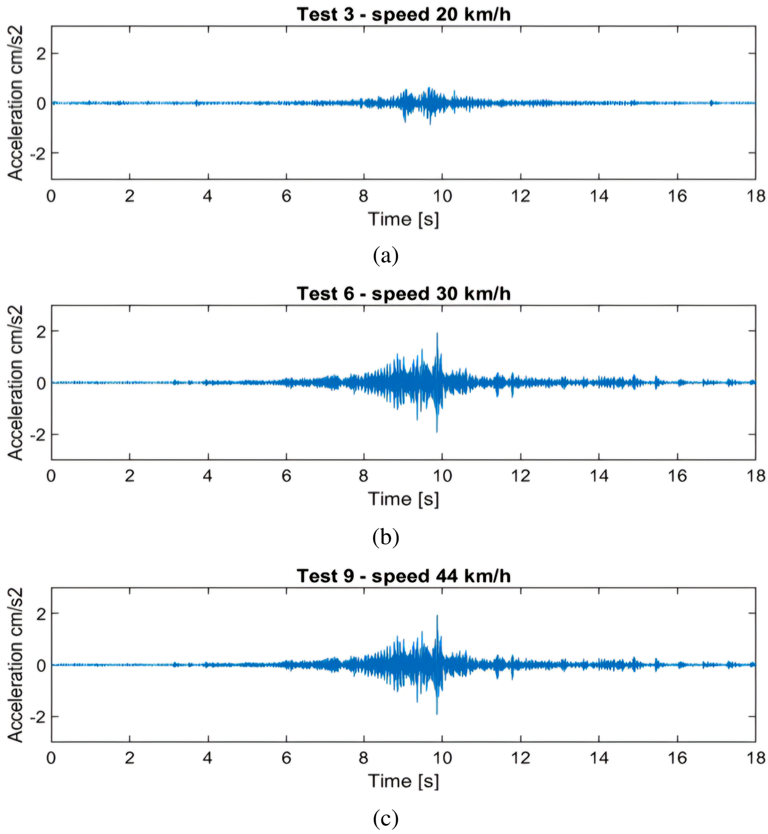

Fig. 5. Representative time histories in the z-direction recorded on the top storey for vehicle speeds: (a) 20 km/h, (b) 30 km/h and (c) 44 km/h

4.2. Mean acceleration amplitudes

To quantify the overall dynamic response of the building for different vehicle speeds, peak acceleration amplitudes obtained from the time histories were averaged for each storey and direction. For every run, the maximum absolute acceleration in the x, y and z-directions was determined; then the results from passages with the same nominal velocity (20, 30, 40, 43 and 44 km/h) were averaged. The resulting mean peak accelerations are shown in Fig. 6a– 6c for the ground floor, first floor and uppermost storey respectively.

In the x-direction (perpendicular to the road axis, Fig. 6a), the highest mean amplitudes are obtained on the ground floor for all speed levels. The values on the ground floor are several times larger than those on the first floor and clearly higher than those on the uppermost storey. The second floor exhibits intermediate amplitudes, systematically larger than those on the first floor but much smaller than the ground-floor values. An increase of vehicle speed from 20 to 44 km/h results in a noticeable growth of the mean peak accelerations on the ground floor, whereas the changes on the upper storeys are more moderate.

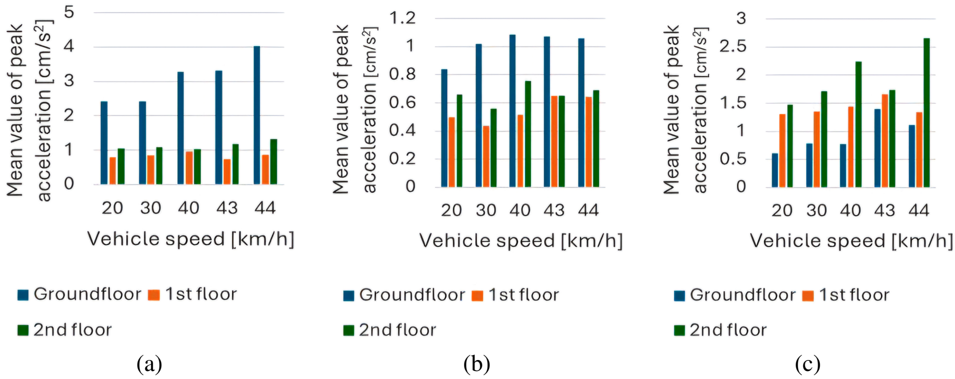

Fig. 6. The mean values of peak acceleration in different directions: (a) x-direction, (b) y-direction, (c) z-direction

In the y-direction (parallel to the road axis, Fig. 6b), a similar qualitative pattern is observed, although the absolute amplitudes are considerably smaller. Again, the ground floor shows the largest mean accelerations for all vehicle speeds, the first floor the smallest, and the uppermost storey intermediate values. The dependence on speed is weaker than in the x-direction, with only a slight increase of amplitudes between 20 and 40-44 km/h.

The vertical component (z-direction, Fig. 6c) reveals a different behaviour. Here, the smallest mean amplitudes are recorded on the ground floor, while the uppermost storey is characterised by the largest vertical accelerations, particularly for the highest vehicle speeds. The first floor shows intermediate values. The influence of speed is clearly visible: both the first floor and the uppermost storey exhibit a systematic increase of mean vertical amplitudes with increasing velocity, with the most pronounced growth for the top storey between 20 and 44 km/h.

Overall, the mean acceleration amplitudes indicate that the horizontal response in the x-direction is dominated by the ground floor, whereas the vertical response is governed by the uppermost storey. The first floor is consistently the least affected in all directions. This non-uniform distribution between storeys suggests a more complex mode shape pattern of the building-soil-structure system, with horizontal rocking effects dominating at ground level and vertical amplification occurring towards the top storey. In the next subsection, these observations are further analysed in terms of the WODL indices that directly reflect vibration comfort.

4.3. WODL indices and vibration comfort

For the assessment of vibration comfort, the measured accelerations were processed in accordance with PN-B-02171:2017 [22]. For each vehicle passage and each measurement point, frequency-weighted RMS accelerations in one-third-octave bands were converted into WODL indices. Table 2 lists, for all ten tests, the dominant one-third-octave band and the corresponding WODL value in the three orthogonal directions for sensors located on the ground floor (Disk 1: P-04x, P-05y, P-06z), the first floor (Disk 2: P-07x, P-08y, P-09z) and the uppermost storey (Disk 4: P-13x, P-14y, P-15z).

Table 2. The WODL value for the dominant one-third-octave band for each test

Measurement No	P-04x		P-05y		P-06z		P-07x		P-08y		P-09z		P-13x		P-14y		P-15z	
	Disc 1 – Groundfloor						Disc 2 – I floor						Disc 4 – II floor					
	f [Hz]	WO DL	*f* [Hz]	WO DL	*f* [Hz]	WO DL	*f* [Hz]	WO DL	*f* [Hz]	WO DL	*f* [Hz]	WO DL	*f* [Hz]	WO DL	*f* [Hz]	WO DL	*f* [Hz]	WO DL
1 – speed 20 km/h	16.00	0.09	80.00	0.03	63.00	0.01	16.00	0.11	10.00	0.09	16.00	0.04	16.00	0.17	10.00	0.13	20.00	0.03
2 – speed 20 km/h	40.00	0.13	80.00	0.05	12.50	0.01	12.50	0.14	10.00	0.09	12.50	0.04	12.50	0.17	10.00	0.13	20.00	0.04
3 – speed 20 km/h	31.50	0.05	80.00	0.01	8.00	0.01	12.50	0.06	10.00	0.03	40.00	0.02	8.00	0.07	10.00	0.04	12.50	0.01
4 – speed 20 km/h	40.00	0.05	63.00	0.02	63.00	0.01	12.50	0.04	8.00	0.02	16.00	0.01	16.00	0.07	8.00	0.02	16.00	0.01
5 – speed 30 km/h	40.00	0.08	80.00	0.03	63.00	0.01	12.50	0.06	10.00	0.03	40.00	0.02	8.00	0.07	10.00	0.04	20.00	0.02
6 – speed 30 km/h	40.00	0.07	80.00	0.02	63.00	0.01	12.50	0.10	10.00	0.07	12.50	0.02	12.50	0.12	10.00	0.07	20.00	0.02
7 – speed 40 km/h	40.00	0.09	80.00	0.03	63.00	0.01	12.50	0.13	10.00	0.04	12.50	0.03	12.50	0.12	10.00	0.06	20.00	0.03
8 – speed 43 km/h	40.00	0.13	63.00	0.03	63.00	0.02	12.50	0.12	12.50	0.05	40.00	0.04	12.50	0.17	12.50	0.05	12.50	0.03
9 – speed 44 km/h	40.00	0.09	80.00	0.03	63.00	0.01	12.50	0.11	12.50	0.04	12.50	0.02	12.50	0.14	12.50	0.05	12.50	0.03
10 – speed 40 km/h	40.00	0.10	80.00	0.03	12.50	0.01	12.50	0.09	10.00	0.05	12.50	0.02	12.50	0.13	10.00	0.07	20.00	0.02

The WODL values obtained in the study range from 0.01 to 0.17. The largest indices are systematically associated with the horizontal x-direction, i.e. with sensors P-04x, P-07x and, in particular, P-13x. For the uppermost storey, P-13x reaches a maximum WODL value of 0.17 (for several passages at 20 and 43 km/h). On the first floor, the sensor P-07x reaches slightly higher values, up to 0.14, whereas on the ground floor the corresponding maximum WODL at P-04x is only slightly lower and equals 0.13. Thus, the most unfavourable conditions occur in the attic, the ground floor is only moderately less exposed, and the first floor is characterised by the smallest WODL indices.

In contrast, the vertical components (P-06z, P-09z, P-15z) exhibit very low WODL values. Their maxima do not exceed 0.02-0.04, i.e. they are several times smaller than the corresponding horizontal x-direction indices. The y-direction (parallel to the road axis) takes an intermediate position: its maxima at P-05y, P-08y and P-14y lie in the range 0.05–0.13, with the highest value 0.13 again observed on the uppermost storey (P-14y). These results clearly show that, in the analysed case, the perception of vehicle-induced vibrations is governed primarily by horizontal motion in the x-direction, rather than by vertical motion, which is more commonly reported as critical in vibration comfort studies. This conclusion may differ from a comparison based solely on peak accelerations because WODL is not a direct time-domain peak measure. WODL is derived from frequency-dependent vibration levels (dominant band content) and referenced to direction-specific 29 perception limits; therefore, a direction may exhibit higher instantaneous peaks but still yield a lower WODL if the response is short-lived and/or concentrated in less sensitive frequency ranges.

When the WODL values are grouped according to vehicle speed, a general tendency of increasing indices with velocity can be observed, although the dependence is not strictly monotonic. For passages at 20 km/h, maximum WODL values in the x-direction already attain 0.17 on the uppermost storey and 0.13 on the ground floor. For 30 km/h, the indices on all storeys increase compared with the lowest speed, while for the highest speeds (40–44 km/h) the WODL values in the attic and on the ground floor remain at their maximum levels (up to 0.17 and 0.13, respectively), with only a moderate increase on the first floor. The observed scatter between tests with the same nominal velocity reflects the impulsive character of the excitation and the sensitivity of the building-soil-vehicle system to small variations in approach conditions.

Despite the relatively high values in the x-direction, all WODL indices remain below the comfort limit values recommended in PN-B-02171:2017 [22] for living rooms during daytime and nighttime use. Nevertheless, the results indicate that the combination of higher vehicle speeds and the uppermost storey leads to the most unfavourable comfort conditions, with the ground floor subjected to only slightly lower vibration levels. From the viewpoint of residential comfort, this confirms that speed management on local roads equipped with speed bumps can directly influence the vibration environment not only in top-floor rooms, but also at ground level.

5. Conclusions

Based on in-situ measurements of floor vibrations induced by a passenger car driving over a speed bump near a residential building, the following main conclusions can be drawn:

1. The excitation from the speed bump generates short, impulsive vibrations with one-two dominant peaks and rapid decay. Vertical accelerations increase with height, with the largest values on the uppermost storey and the smallest on the first floor.

2. Mean acceleration amplitudes show a non-uniform distribution: horizontal motion in the x-direction (perpendicular to the road) is dominated by the ground floor, whereas vertical motion is governed by the uppermost storey. This indicates a more complex mode-shape pattern than a simple monotonic increase from bottom to top.
3. The comfort assessment based on WODL shows that the most unfavourable conditions are associated with the horizontal x-direction. For all storeys, WODLxis clearly higher than in the y and z directions, and the largest values occur in the attic, with only slightly lower values on the ground floor. Thus, in the analysed case, horizontal motion governs perception, contrary to the common assumption that vertical vibrations are always critical.
4. Mean amplitudes and WODL indices generally increase with vehicle speed, although the relationship is not strictly linear and some scatter appears between runs at the same speed. However, for all tests, the WODL values in each direction remain below the corresponding comfort lines specified in PN-B-02171:2017 for residential rooms, so the comfort criteria are not exceeded.
5. Even when comfort limits are not violated, speed bumps can generate noticeable horizontal vibrations in nearby dwellings. For similar buildings it is recommended to evaluate comfort in all three directions and to coordinate the placement of traffic-calming devices and local speed limits with a vibroacoustic assessment, paying particular attention to top-storey and ground-floor rooms closest to the road.

The above conclusions clearly indicate the complexity of the problem under investigation. Therefore, further research appears justified to clarify and achieve a deeper understanding of the effects of velocity on the structure and its occupants. Future work will focus on three main areas: expanding the set of real-case studies, numerical models, and examining in more detail the influence of traffic and road parameters. First, it is planned to carry out analogous in-situ measurements in other buildings with different geometry, stiffness and foundation conditions. In parallel, numerical models representing the building, subsoil and vehicle crossing the speed bump should be developed and calibrated against the recorded time histories and WODL values. Such models will make it possible to identify the mode shapes responsible for the increased indices in the x-direction and to explain the amplification of the response on the ground floor and top storey. A third research direction is a systematic analysis of the influence of traffic and road characteristics, including different speed ranges, acceleration and braking patterns near the bump, various bump geometries and pavement conditions, and different vehicle masses.

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Wpływ prędkości pojazdu na komfort wibracyjny mieszkańców w budynku mieszkalnym

Słowa kluczowe: drgania od ruchu drogowego, komfort wibracyjny mieszkańców, prędkość pojazdu, próg zwalniający, wskaźnik WODL

Streszczenie:

Artykuł dotyczy oceny wpływu prędkości samochodu osobowego na komfort wibracyjny mieszkańców w niskim budynku mieszkalnym zlokalizowanym przy drodze lokalnej wyposażonej w próg zwalniający. Analizowany obiekt stanowi trzy kondygnacyjny budynek w zabudowie bliźniaczej, zaprojektowany jako dwulokalowy, z częścią parterową oraz dwiema kondygnacjami nadziemnymi (pierwsze piętro i poddasze użytkowe). Budynek posadowiono na ławach fundamentowych, a jego ustrój nośny tworzy układ murowo-żelbetowy z monolitycznymi płytami stropowymi. Obiekt spełnia aktualne wymagania w zakresie izolacyjności cieplnej przegród oraz wyposażony jest w instalacje sprzyjające niskoemisyjnej eksploatacji (m.in. wentylację mechaniczną z odzyskiem ciepła i instalację fotowoltaiczną). Celem badań było określenie, w jaki sposób zmiana prędkości przejazdu samochodu osobowego przez próg zwalniający wpływa na poziom drgań podłóg na poszczególnych kondygnacjach oraz na ocenę komfortu wibracyjnego mieszkańców według PN-B-02171:2017. W tym celu wykonano pomiary przyspieszeń drgań podłóg na parterze, pierwszym piętrze i poddaszu użytkowym. Czujniki przyspieszeń zamocowano na płytach stropowych w trzech wzajemnie prostopadłych kierunkach: dwóch poziomych (x – prostopadły do osi drogi, y – równoległy) oraz pionowym z. Pomiary prowadzono dla serii dziesięciu przejazdów samochodu o masie ok. 1,8 t przez próg zwalniający, przy zróżnicowanej prędkości w zakresie od 20 do 44 km/h. Rejestrowane przebiegi czasowe charakteryzowały się krótkotrwałym, impulsowym charakterem odpowiedzi, związanym z przejazdem osi pojazdu przez próg, oraz szybkim wygaszaniem drgań. Na podstawie sygnałów wyznaczono maksymalne amplitudy przyspieszeń w trzech kierunkach oraz ich średnie wartości dla grup przejazdów o tej samej prędkości. Wyniki pokazały złożony rozkład przestrzenny odpowiedzi: w kierunku pionowym największe średnie amplitudy odnotowano na najwyższej kondygnacji, natomiast na parterze były one wyraźnie niższe, lecz nadal istotne. Pierwsze piętro charakteryzowało się najmniejszym poziomem drgań we wszystkich kierunkach. W kierunku poziomym prostopadłym do osi drogi (x) dominującą odpowiedź stwierdzono na parterze, co wskazuje na istotny udział ruchów kołyszących i oddziaływania układu grunt-budynek-pojazd. Ocenę komfortu wibracyjnego przeprowadzono w oparciu o wartości skuteczne przyspieszeń ważonych częstotliwościowo i odpowiadające im wskaźniki WODL, wyznaczone w pasmach tercjowych zgodnie z procedurą normową. Dla każdego przejazdu i każdego punktu pomiarowego określono częstotliwość dominującą oraz wartość WODL, a następnie porównano je z liniami komfortu dla poszczególnych kierunków drgań. Uzyskane wartości WODL mieściły się w zakresie od 0,01 do 0,17. Największe wartości notowano w kierunku poziomym x, przede wszystkim na poddaszu użytkowym (maksymalnie WODL = 0,17) oraz na parterze (do WODL = 0,13). W kierunku równoległym do drogi (y) wartości WODL były umiarkowane, natomiast w kierunku pionowym z przyjmowały wartości kilkukrotnie niższe (zwykle ≤ 0,04). Oznacza to, że w analizowanym przypadku o odczuciu drgań decyduje głównie poziomy ruch budynku prostopadły do osi drogi, a nie komponent pionowy, który w wielu innych badaniach jest uznawany za wiodący z punktu widzenia komfortu.

Analiza wpływu prędkości przejazdu wykazała ogólną tendencję wzrostu amplitud i wskaźników WODL wraz ze wzrostem prędkości pojazdu, przy czym zależność ta nie ma charakteru ściśle liniowego. Największy przyrost wartości obserwowano przy przejściu z 20 do 30 km/h; dalszy wzrost prędkości do 40-44 km/h prowadził do umiarkowanego zwiększenia lub stabilizacji wartości WODL, z pewnym rozrzutem wyników między poszczególnymi przejazdami. Zjawisko to wiąże się z impulsowym charakterem

wymuszenia oraz wrażliwością układu grunt-budynek-pojazd na niewielkie różnice w warunkach najazdu na próg. We wszystkich analizowanych punktach pomiarowych wartości WODL w poszczególnych kierunkach pozostawały poniżej odpowiednich linii komfortu określonych w PN-B-02171:2017 dla pomieszczeń mieszkalnych, co oznacza, że kryteria komfortu nie zostały przekroczone. Mimo to wyniki jednoznacznie wskazują, że zwiększenie prędkości pojazdu prowadzi do istotnego wzrostu poziomu drgań, a najbardziej niekorzystne warunki panują na najwyższej kondygnacji oraz – w nieco mniejszym stopniu – na parterze budynku. Z praktycznego punktu widzenia potwierdza to konieczność uwzględniania wpływu urządzeń uspokajania ruchu na komfort wibracyjny mieszkańców w bezpośrednim sąsiedztwie drogi oraz potrzebę oceny drgań we wszystkich trzech kierunkach, bez z góry przyjętego założenia, że komponent pionowy będzie zawsze dominujący.

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