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Procedia Engineering 199 (2017) 2693–2698

Procedia Engineering

www.elsevier.com/locate/procedia

X International Conference on Structural Dynamics, EURODYN 2017

The environmental impact of the vibration induced by the passage of trains at various speeds

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Abstract

Vibration from railways has a negative impact on the surrounding area. During homologation tests of the Pendolino (EMU 250), the vibrations of building have been measured during the passage of the trains at speeds varying between 40 and 250 km/h. In situ measurements were conducted by the staff of the accredited Laboratory of Structural Mechanics at Cracow University of Technology. The tests took place in Poland. The study presents a selection of vibration measurement results and discusses the negative environmental impact caused by the passage of different kinds of trains at various speeds. The evaluated building was located at distance of approximately 50m from the track. Two sensors recording the horizontal vibrations were fixed on the building foundation at ground level in accordance with the applicable Polish standards. Assessment of the impact of vibrations on the building was identified using the scales of dynamic influences (SDI scales) according to Polish standards and indicators of the perceptibility of vibration through constructions (WODB). The results are presented by graphs in frequency domain.

Peer-review under responsibility of the organizing committee of EURODYN 2017.

Keywords: Pendolino train; SDI scale; WODB

1. Introduction

It is well known that vibration from railways has a negative impact on the surrounding area. Several standards and laws [1-3] govern the issue of vibration emission. With the attention paid to this subject in international literature (inter alia [4-6]), it is clear that the issue of vibration induced by trains is an important consideration

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1877-7058
Peer-review under responsibility of the organizing committee of EURODYN 2017.
10.1016/j.proeng.2017.09.558

throughout the modern world. The increases in train speed and the creation of new high-speed lines increases the size of this problem. Some observations of the effects and the scale of the problem in close proximity to railway tracks have been reported in [7, 8].

Nomenclature

SDI	Scales of Dynamic Influences
WODB	Indicator of perceptibility of vibration through construction

2. Background

Before the authorisation for the use of the newly purchased Pendolino trains, homologation and velocity tests were conducted in Poland. One of the new trains (Electric Multiple Unit - EMUs 250) was tested whilst crossing the Psary – Góra Włodowska section (approximately 36km in length) located within railway line No. 4. The train was running at predetermined speeds – varying between 40 and 293km/h.

A PCB Piezotronics piezoelectric accelerometer and a SCADAS Mobile LMS International analyser were used to perform measurements. Accelerometers were fixed on the building foundation, at ground level. Mounting the sensor on the foundations was carried out according to the method featured in [9]. The investigated residential building was 50m from track no. 1. The surveyed property is a typical residential masonry building. The tracks and structures were separated by a shallow drainage ditch. The trains were on track no.1. The measuring polygon and the schematic arrangement of the sensors are shown in Fig. 1.

The study presents selected results of measurements of building vibration (horizontal components of vibration: x – perpendicular to the axis of the track; y – parallel to the axis of the track). The accelerometers used to measure 'x' and 'y' vibrations were labelled P-01x and P-02y, respectively. Analyses were performed based on the knowledge and experience of the researchers and are also available in references [10-16].

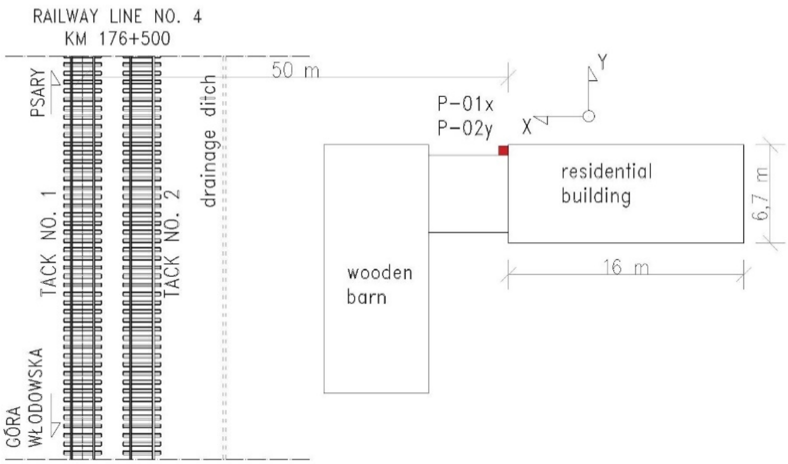

Fig. 1. Measuring polygon – schematic arrangement of sensors.

3. Analysis

3.1. Analysis of SDI and WODB

Assessment of the vibration harmfulness of the building was done according to Polish standard [17] using scales of dynamic influences (SDI scales). Dimensions of the examined building classify it as being within the scale SDI - II. The measured signals of the horizontal acceleration were analysed using one-third octave band frequency filters.

The results of the horizontal vibration (from sensors P-01x and P-02y) recorded during the passage of trains at speeds of v = 250km/h are presented in Fig. 2(a). These vibrations are not harmful to any part of the building because all acceleration values in one-third octave bands are located in the first zone of the SDI scale (below the black line).

Furthermore, in order to simplify the presentation of data, the indicator of perceptibility of vibration through the construction (WODB) was entered. The indicator is the largest value of the ratio of the vibration acceleration parameters in one-third octave bands to the acceleration corresponding to the lower limit consideration of the dynamic influence on buildings due to the SDI scales in the same frequency band. The WODB indicator directly displays how many times the lower limit consideration of dynamic influence on buildings has been exceeded. Fig. 2(b) shows the results of the recorded horizontal vibrations (sensors P-01x and P-02y) from the passage of trains at speeds of v = 250km/h.

The investigation and analyses proves that using the new trains doesn't have a negative impact on the environment as a result of vibration.

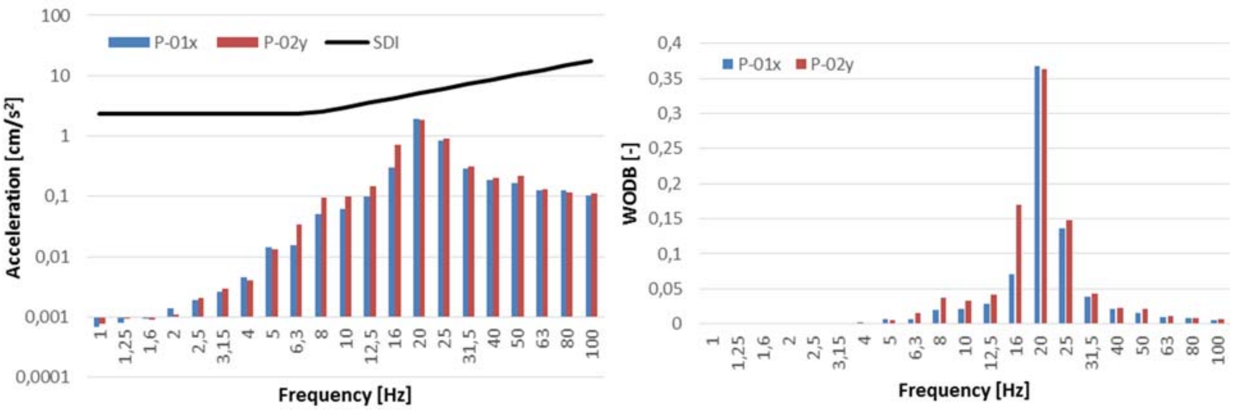

Fig. 2. (a) vibration spectrum in one-third octave bands with SDI scale – Pendolino trains at a speed of 250km/h; (b) WODB spectrum in one-third octave bands – Pendolino trains at a speed of 250km/h.

3.2. Analysis of WODB at variable speed

A method for analysing the frequency characteristics of vibrations at variable speed was to identify the changes in the WODB indicator in each frequency band. For each of the speeds (v= 40, 80, 120, 160, 180, 200, 230, 250km/h), the average WODB indicators in the frequency domain were calculated. The results from the lower speed were subtracted from the higher speed and divided by the length of the speed band. Seven bands of speed were created with information of changes of WODB in this speed band for each one-third octave frequency band.

Fig. 3 shows the obtained values for the P-01x sensor. The blue areas are the places where the WODB decreases as the speed increases. The orange and red areas are locations of increases of both. It should be noted that the most rapid growth occurs with a change in velocity of 200 to 250km/h for a frequency of 20Hz. A similar analysis was performed for the P-02y sensor and the results are presented in Fig. 4. The worst values are also at a frequency of 20Hz and at speed changing 200-230km/h.

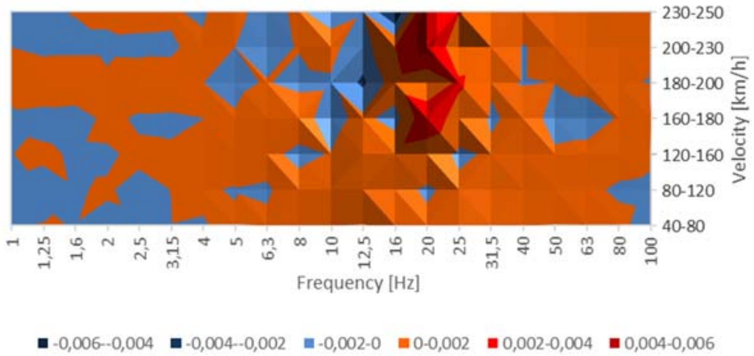

Fig. 3. Graph of variation of WODB - sensor P-01x.

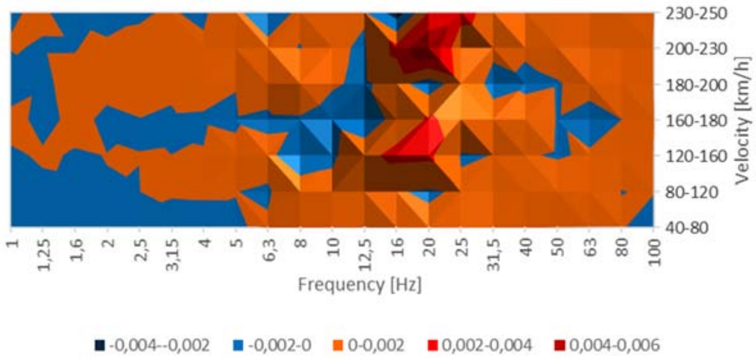

Fig. 4. Graph of variation of WODB - sensor P-02y

The value of WODB at variable speed for two frequency bands (20Hz and 100Hz) for sensor P-01x are shown in Fig. 4. The frequency one with the fastest growth of the WODB indicator was 20Hz; for the purposes of comparison, the frequency of 100Hz is also shown. Growth curves of values of WODB versus velocity of the EMU 250 were fitted. The exponential function is given for each set of data. It describes the dependence of the WODB on train speed. The maximum values of vibration acceleration showed a significant difference depending on the one-third octave frequency band. The WODB values corresponding to a frequency of 20Hz are often higher and grow much faster.

Fig. 5 displays similar values as those described above obtained from the P-02y sensor. The conclusions are of the same as those reported for the P-01x sensor. It should also be noted that not all frequencies are equally sensitive to speed increases. For this reason, while planning to increase the speed of a train, we should pay particular attention to damping the respective components. It can be seen that, according to our findings, if we want to increase the speed of passage trains, we should design vibro-isolation damping optimised to frequencies of 20Hz. Results indicate a necessity to devise an appropriate track vibration isolation design.

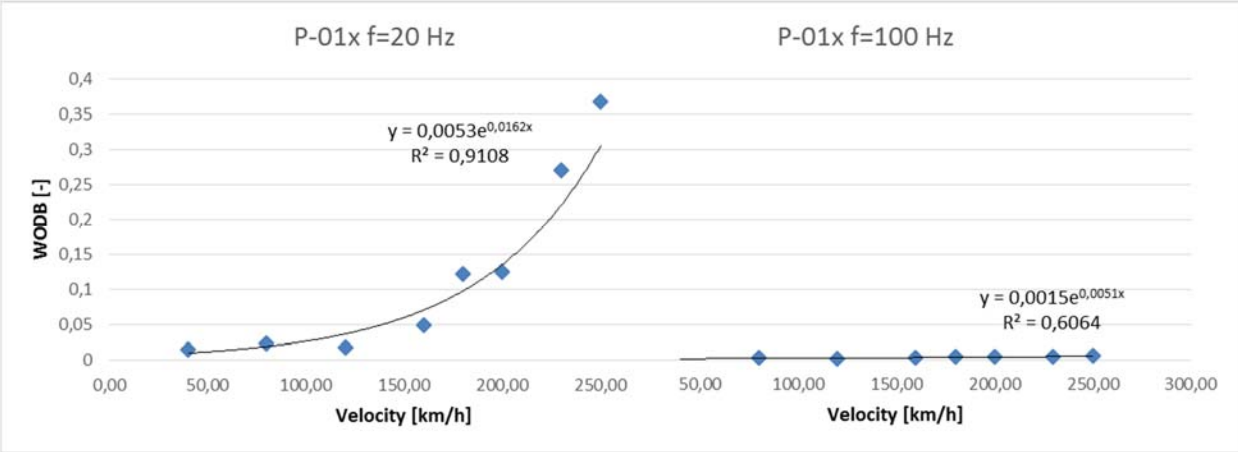

Fig. 5. The value of WODB at variable speed for two frequency bands (20Hz & 100Hz) – sensor P-01x

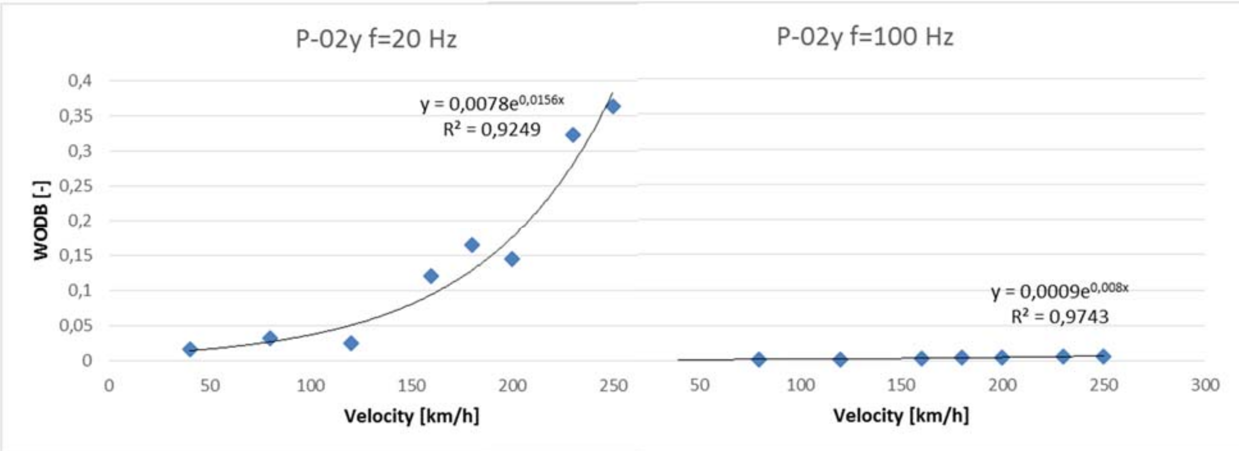

Fig.6. The value of WODB at variable speed for two frequency bands (20Hz & 100Hz) – sensor P-02y

4. Conclusions

This paper deals with the negative impact on nearby structures caused by the passage of the Pendolino trains in Poland. Based on the analysis of measurement data, we can draw the following conclusions:

- Train vibration, due to worldwide literature, is a global concern and a growing engineering challenge. The problem also applies to well-developed countries. For this reason, transport plays a significant role in shaping the quality of the environment.
- Assessment of the environmental impact was presented by an indicator of the perceptibility of vibration through construction (WODB) – this refers to the scales of dynamic influences (SDI scales). The limits specified by standard [17] in any of the occurrences of train passage of speeds of up to 250km/h were not exceeded; however, increasing the speed leads to an increase in the negative impact of the vibration on the examined building.
- The designated frequency spectrum of the vibration records allowed the identification of the dominant frequency bands and their comparison at different speeds. Results indicate a necessity to devise an appropriate track vibro-isolation design. This raises the question of what is the most suitable vibro-isolation strategies for to address the

negative impact of railway vibration. The aim is to provide new thinking on how to create the best isolation for high speed lines.

- Propagation of vibrations from railway lines with their effect on the structural response of buildings is a complex phenomenon; therefore, without in situ measurements, it is difficult to assess the impact of vibration on buildings. As proven above, a train moving on a track at variable speed doesn't uniformly make the vibration higher in each frequency band. According to our findings and in some international literature [18], we could find that the accelerations obtained at frequency 20 Hz are very vulnerable to increasing of train speed. But it isn't a universal law, therefore, in situ measurements are so important.

In conclusion, if we want to increase the velocity of trains, we should not forget about vibration pollution.

Acknowledgements

The authors are grateful to the staff of the Laboratory of Structural Mechanics at Cracow University of Technology. In situ investigations of vibrations were performed by the laboratory.

The authors acknowledge the support of research funded by the Ministry of Science and Higher Education – project L-4/349/2016/DS-M.

References

[1] ISO 14000 - Environmental management

[2] Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment.

[3] Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment.

[4] T. Lawrance, Noise and vibration from road and rail, CIRIA, London, 2011

[5] D. Tompson, Railway noise and vibration, Mechanisms, Modelling and Means of Control, Elsevier, Oxford, 2009

[6] V. V. Krylov, Noise and vibration from high-speed trains, Thomas Telford, London, 2001

[7] D. P.Connolly et al., The growth of railway ground vibration problem – A review, Sci Total Environ, p.1-7, Elsevier, 2015

[8] D. P. Connollya, G. Kouroussisb, O. Laghrouchea, C. Hoc and M. Forded, Benchmarking railway vibrations – Track, vehicle, ground and building effects, Construction and Building Materials, no. 92, p. 64-81, Elsevier, 2015

[9] Maciąg, J. Chełmecki, T. Tatara, Investigation of ground and low-rise buildings vibrations caused by city traffic, Engineering and Construction, pp. 135-140, 5 (PZIiTB, 2005) (in Polish)

[10] T. Tatara, K. Stypuła, Analysis of the results of measurements of ground vibration and some elements of the surface during the test of Pendolino train and other trains on the line CMK in agreed locations in the track No. 1, section Psary - Góra Włodowska, Cracow University of Technology, Cracow, 2013 (in Polish)

[11] L. S. G. Degrande, Free field vibrations during the passage of a Thalys high-speed train at variable speed, Journal of Sound and Vibration, no. 247 (1), p. 131-144, Academic Press, 2001

[12] A. De Sortisa, E. Antonaccib, F. Vestronic, Dynamic identification of a masonry building using forced vibration tests, Emgineering Structures, 27 (2), (2005), p. 155-165

[13] J. Kawecki, P. Stecz, K. Stypuła, On the nesessity of use of simulation calculations of the vibration isolation in the tram track, Technical Transactions,vol. Series : Civil Engineering, no. 3-B, p. 163-173 (2011) (in Polish)

[14] X. Sheng, C. J. C. Jones, M. Petyt, Ground vibration generated by a load moving along a railway track, Journal of Sound and Vibration, 228(1) (1999), 129-156

[15] R. Ciesielski, A. Kwiecień, K. Stypuła, Vibration propagation in layers closed to the surface of the soil – Experimental investigation in situ (Cracow University of Technology, Cracow, 1999) (in Polish)

[16] K. Stypuła, Effect of vibration of communication on buildings and people staying in them, p. 120-131, Building Materials, no. 3, SIGMA-NOT, 2009 (in Polish)

[17] PN-85/B-02170:1985, Evaluation of the harmfulness of building vibrations due to ground motion (in Polish)

[18] H. V. C. Howarth, M. J. Griffin, The relative importance of noise and vibration from railways, Applied Ergonomics, Vol. 21, Issue 2, p. 129-134, Elsevier, 2009