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Noise of Railway Transport and Its Impact on the Environment

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ABSTRACT

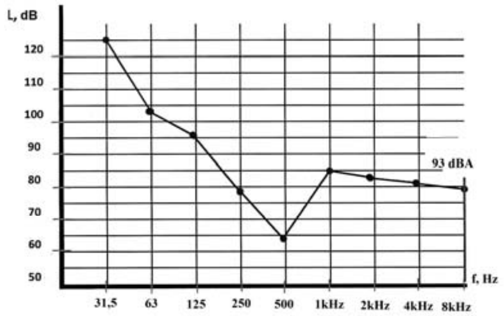
The report deals with the opportunities for the implementation of the EU Rail Baltica strategic study project, evaluating the fulfillment of acoustical requirements for the railway route. The concept of Rail Baltica refers to the imaginative, strategic and sustainable north-south rail project connecting Tallinn in Estonia – via Latvia and Lithuania – with Warsaw in Poland [1-3].
Here evaluate the possible impact of noise caused by the trains on the environment. In the work has been made specific planning and analysis for the project in the countries.
This report is aimed at investigating the noise characteristics of railway transport facilities in their present-day and future use and analyzing the harm of its parameters to the individual and environment, clarifying what measures should be taken to reduce the impact of the possible noise on the individual and the environment.
The report provides sound pressure levels from the passing by trains, which are running and still will run until the reconstruction of the main line; also noise levels are predicted when modernizing road and railway transport means (locomotives, vans, etc.).
A study is made of the spectrum composition of noise produced by the train in terms of quantity and quality of the radiated energy in respect of the human organism, i.e. not only by the sound level dBA, but also by the spectrum composition of sound pressure level. Attention is focused on the impact of very low sound frequencies and infrasound on the environment. On the basis of the measured and calculated noise levels propagated by various future railway trains, the impact of noise produced by the trains on the environment is specified by the method of analysis. Basing on the noise analysis results, measures are foreseen for the reduction of harmful noise propagated by the trains.
The article presents the research on reduction of noise and vibrations by means of screens theory and their implementation in practice. Acoustic screens are divided according to their usage and structures. The article deals with the presentation of screens availability in practice, their theoretical evaluation is submitted as well as their dependence on their structure and materials. Here is presented the evaluation of their positive and negative acoustic properties. The conclusion is derived that screen acoustic properties may be perfected by including into their design new elements , which increase their efficiency in reducing noise effect. Theoretical calculations are submitted and results obtained are analyzed . The conclusion derived states that in the screens there cylindrical , semi-cylindrical or conical elements have to be applied.

INTRODUCTION

That Lithuanian Railway lines are unqualitative and due to such and other reasons a noise level near the passing railway lines is rather high and reaches 110 and more dB(A).
As it is seen from the spectra (Fig.1a, 1b) of sound pressure level of noise transmitted by trains, the highest sound pressure level is at low frequencies (30-100Hz). Though, in some cases sound frequencies may be within the range of infrasound frequencies.
The impact of infrasound on the individual and other environmental organisms in most cases it is negative. It is identified that some low-frequency sounds or infrasound are of negative action: sound at the frequency of 37 Hz causes cardiac, pulmonary and stomach disorders; due to frequently heard 16 Hz frequency the activity of the stomach gets disturbed. It is notable that we can feel very low and high sounds, beyond the limit of hearing, with all the body, like mechanical vibrations, heat and the like. Sounds, with the frequency lower than 16 Hz, are harmful to the individual, causing the unjustified fear, anxiety, fatigue, “sea” disease symptoms, and may be harmful to eyesight and become the cause of the serious health disorders. Especially dangerous is infrasound at the frequency of 7 Hz, since this sound, generating frequencies, while being close to the organs of our body, may disturb the heart or brain activity.
Impact of infrasound on the individual. Infrasound affects people biologically, when its frequency (7-8 Hz) coincides with the alpha rhythms of the brain (flows of certain frequency). The frequency of sounds of 18-19 Hz coincides with the resonance frequency of eyes; therefore it may cause optical illusions. This may be very dangerous when driving the means of railway transport and the like [4].
When conducting research of the impact of infrasound on the environment, it was established that infrasound waves may cause the feeling of fear and anxiety. Infrasound of 120 dB

(and stronger) is very dangerous to the human organism; in addition, infrasound waves may ruin or damage the constructions of buildings. At the present moment, the infrasound weapon of mass destruction has been created, the operation of which is based on the inducement and use of powerful infrasound vibrations (frequency of 16 Hz). Infrasound waves affect the central nervous and digestive system, cause pain of the head and internal organs, and interfere with the rhythm of respiration. Giddiness, vomiting, loss of consciousness, and blindness may become manifest. Infrasound also has an effect on human consciousness (the individual fails to control his actions), arouses the feeling of horror, which sometimes is the cause of death. Table 1, on the basis of research of scientists, shows the impact of infrasound of certain intensity on the individuals.

a)



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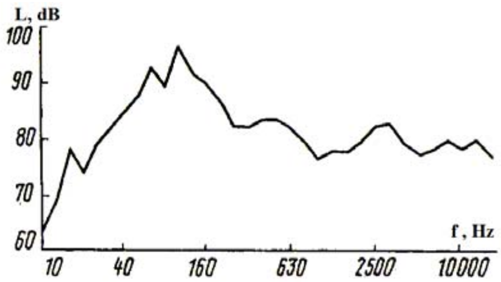

Figure 1a, 1b. A typical diagram of sound pressure levels, produced by the train locomotives (2a) and by the train (2b) . Used in the present-day Lithuanian railway lines, running at a speed of up to 160 km/h, at a distance of 5.25 metres from the rail (94 dBA). The hygiene norm is from 70 to 90 dBA, depending on the objects which are passed by the train.

Table 1. Degree and volume of the impact of the intensity of infrasound

Degree of infrasound impact	**Infrasound power level(dB)**	**Infrasound impact**
I (fatal)	>185	Pulmonary alveoli get ruptured
II	140 - 172	The individual may endure 2 min.
III	120 - 145	The reaction time becomes longer, it is difficult for him to concentrate
IV	< 120	The individual feels fatigue more quickly, sea sickness signs appear

People, living near the urban area, close to the railway lines, which are located under the viaducts and other road facilities, complain that the generated infrasound from the passing train are felt in the residential houses (see fig. 2).

Figure 2. Of noise and vibration, excited by the moving train

Noise in the territory near the main road, propagated into the surrounding space, during the train movement is the most important constituent of the noise of trains. Noise in the territory near the main road depends on different factors, such as the interaction of the rolling stock and the line, vibrations of constructions, speed of the train movement, length of the stock, turbulence of air flows, aerodynamic forces at high speeds (i.e. > 250 km/h), etc.

At present as regards the transport harmful impact on the environment, it is related not only with the radiating, audible sound (noise), but also with the vibrations and their excited infrasound. Therefore in the project "Rail Baltica" it is foreseen together with the screens reduction of vibration to implement the measures for noise well.

Many railway lines were built long ago and not taking into account the noise impact on the environmental territory. Townships and villages, near which the fast railway networks are laid, experiences harm (noise, vibrations and infrasound). For solving this problem the joint efforts of the state, local administration and railway companies are needed. Planning new railway lines according to the project "Rail Baltica", the optimum railway line designing is needed, taking into account a distance from the road to the closest building and the land excavation. To reach the noise level normative values, for reduction of the effect, it is necessary to perform the additional research works and evaluation of the impact of noise on the environment before the beginning of the constructions, the predicted railway noise and vibrations impact and the necessary measures of their reduction at the stage of designing.

In order to reduce the noise transmitted by railway transport, noise screens will be installed. It was designed to implement in the "Rail Baltica" project described by us. Therefore, in this work the major attention will be focused on the use of noise screens and their elements to reduce the noise transmitted by trains.

CONSTRUCTION OF ACOUSTIC SCREENS AND THEIR PROPERTIES FOR NOISE REDUCTION

In world practice at present numerous acoustic screens of various types against noise are used. Both their destination and constructions vary. As to those differences, they could be subdivided into several groups, namely, screens for noise reductions, screens for vibration damping, and vibroacoustic screens that retain vibration and noise. Their efficiency is predetermined by a great number of various requirements. These are materials with their own properties, their dimensions, etc. One of the more important requirements is the vibroacoustic properties of materials. Their possible efficiency is calculated on the basis of vibroacoustic parameters, and preconditions are formed for dimensions and forms of shield constructions. The constructions and forms of screens have a more significant impact on the noise permeability, i. e. its reduction when passing over to the silent side of the screen. In our work [5,6] the effect of wall rigidity on sound insulation of the acoustic screens was studied. The form of screen elements and the final shield construction as well as screen impedance have an effect on increasing the rigidity. How should an acoustic shield look like as regards its form so as it would have many vibroacoustic properties in reducing noise and vibrations? It is still more difficult to respond to this question, since no single opinion exists on this issue. A good number of other requirements are also set in respect of the form of shield construction. Of those more important is its aesthetic appearance, as well as ecological requirements. Therefore comprehensive work should be carried out in this direction aimed at solving all the problems relating to acoustic screens. In this paper we will attempt to present the samples for solving those problems.

Our theoretical calculations [5,6] are based on increasing the rigidity of construction. However, other properties of materials and constructions, like, for example, various resonances, elasticity, etc. also have a great impact. An important requirement set for the screens is the evaluation of the environment where the screen will be used; the environment, specifications of noise propagated in it and vibration sources. Some of those more important would be the spectra of their propagated noise or vibrations, where the location of the values of the power of propagating noise or vibration parameters by frequency would be seen. Therefore this information provides requirements for acoustic screen construction. Theoretical fundamental decisions give and idea most frequently how to use theoretical conclusions in some cases.

The paper provides our theoretical justifications carried out for implementation of the proposed measures.

EVALUATION OF SCREENS EFFICIENCY

The application of screens for noise and vibration reduction has been known since the time the problem has become urgent not to be ignored. In order to avoid noise the first radical attempts were made by isolating in the premises the sources of high intensity noise from the sources radiating lower noise.

The article presents the analysis of screens to be applied in reducing the traffic noise, the analyzed source is considered as the noise heard from the railway interfering into the people's activity zone and into the living area.

The efficiency of the screens could be determined by experimenting or by carrying out calculations.

The produced screen efficiency could be determined by means of the experiment in the surrounding environment, namely determining the place it would be placed whether in the laboratory in the field of freely propagating sound, namely under the conditions of free field, in the charged chambers.

However, the best method for evaluation the screens is to apply both methods namely, to calculate various variants and after having received in this way the best variant try to apply experimenting. In order to select and calculate the required screens with such an efficiency to be able to reduce the level of noise up to the indicated values in the directives then it is required to carry out additional researches, namely to determine the characteristics of the noise intended to be reduced.

With the help of these characteristics of the noise it is possible to compile noise reduction model and select by means of the calculation method the determined noise reduction means, screens are included here.

That is why, first of all we have to possess theoretically grounded screen model, the methodology of calculation of which depends on the design of the screen that is on what elements and materials it is compiled and what materials could be applied in designing acoustic screens One more component that is very important to be considered is the parameter of the screen design as well as its height.

As the world experience of the screen application indicates there may be various screen designs in accordance with the materials used and different dimensions [7-15].

The bases of the acoustic screen design is made of a bearing frame and sound isolating part with additional sound absorption and protection layers.

The effective screen height H_e is determined in accordance with the calculation scheme presented in figure 3.

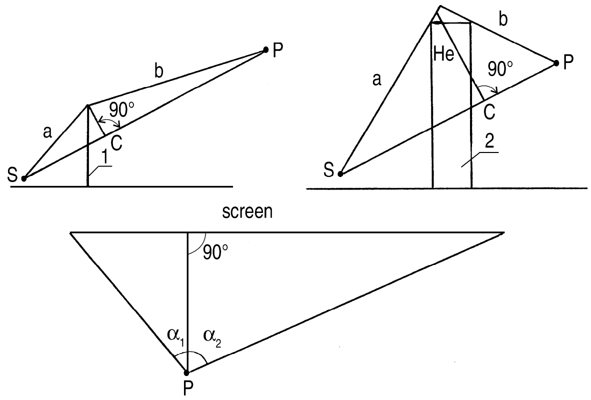

Figure 3. Calculation schemes for determining the lowering of the noise level on the screen: 1 – barrier, 2 – building, S – noise source, P – count point, He – effective height of the creen

CALCULATION OF THE SIMPLE SCREENS

In the final calculation, when we have the characteristics of the screen, in order to evaluate the qualitative side of the screen we have to follow the theory of diffraction [7-9].

In order to obtain sound pressure at a certain point P in the zone of the shadow, behind the screen it is necessary to integrate energy, radiating by every single elementary volume of the wave front, acting as the qualitative new source point in the free space above the screen.

Many authors [7,9] proposed their own theories that analyze different conditions of the fall of the sound waves. Strong and accurate decisions are used only for very clean and simple conditions which do not exist in the reality. Besides that simplicity is good for practical calculations and may be successfully applied in designing the screens aimed for protection of noise.

The sound field in the point *P*, after having passed through the window makes itself the factor of diffraction (*DF*) on the field in the free space.

Here we are going to analyze semi-infinite thin screen with the point source. For the most simple case semi-infinite flat screen is installed between the points *S* and *P* with the values $u_{1....(}$)

$$DF = \frac{-i}{2}(1+i)\left\{\left[\frac{1}{2} - C(v_1)\right] + i\left[\frac{1}{2} - S(v_1)\right]\right\} \qquad (1)$$

Lowering of noise by means of semi-infinite screen is expressed in the following (2)

$$\Delta L_{1/2} = -10\lg|DF|^2 = -10\lg\frac{1}{2}\times\left\{\left[\frac{1}{2}-C(v_1)\right]^2+\left[\frac{1}{2}-S(v_1)\right]^2\right\} \quad (2)$$

where the bracketed terms correspond to the square of the absolute value of the vector v_1 to *Q*, [7,8].

The graph in the figure 4 demonstrates the results of the calculations by means of the equation (2). The area of negative and positive values corresponds to the position of the point *P* in the zone of the shade and out of the shade.

The equation (2) received from the theory of diffraction in optics has got a very simplified view and the most clearly represents the physical essence of the phenomenon, It's a pity that a good approximation with an optical diffraction doesn't ensure the same accuracy in the acoustics. In optics the length of the waves are very low, at the same time the distance from the source to the obstacle and further on to the observer is high enough. The conditions in acoustics are quite different that is why when designing acoustic structures and screens it is recommended to apply empirical data.

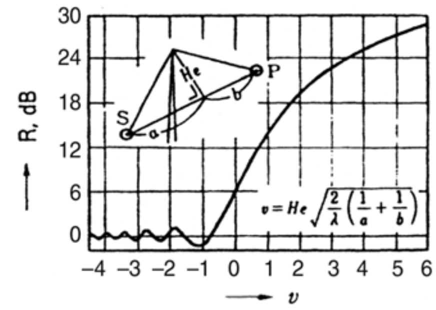

Figure 4. The calculated lowering of sound of semi-infinite screens following the theory of diffraction of Kirchhoff (for comparison with free space)

ANALYSIS OF THEORY AND PRACTICAL IMPLEMENTATION

The efficiency of screens noise reduction depends on the characteristics of the sound isolation and sound absorption as well as on the above mentioned characteristics. Based on the theory presented in [11,12] it was determined that in the acoustic screens after application of cone type element it is possible to increase the isolation and sound absorption characteristics of the above mentioned used screens.
The efficiency of screens noise reduction depends on the characteristics of the sound isolation and sound absorption as well as on the above mentioned characteristics. Based on the theory presented in [5,6,12] it was determined that in the acoustic screens after application of cone element it is possible to increase the isolation and sound absorption characteristics of the above mentioned used screens. Special noise absorbers with cone element installed on the screen (Fig.5) not only absorb low frequency sound better, but also improve sound isolation.

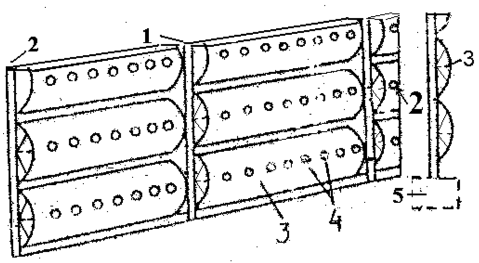

Figure 5. The screen model with the cone elements. 1. Plate, 2 stand, 3 Sound absorption of cone element, 4. Opening, 5. Foundation

In analyzing the obtained results it is possible to state that after using cone **e**lements for the structures of acoustic screens, the characteristics of screens sound absorption and isolation would increase especially under low frequencies (see fig. 5).
Sound reflected from the screen actuates the vibrations of the barrier of the screen which also radiates sound corresponding frequencies. So the vibrations actuated by the screen barrier should be very low frequency or very high frequencies, namely in the range of not audible sound frequency.
The proposed acoustic screen to be viewed as an equipment with specially designed sound absorbers, that not only absorb the reflected sound but improves the characteristics of but also improves the characteristics of screen sound isolation.

CONCLUSION

1) While studying low-frequency sounds, which are propagated from railway transport, it was established that audible low-frequency sound is accompanied by infrasound.
2) It was established that infrasound while propagating in the environment has a negative impact on the individuals and on the fauna.
3) It has been determined that for the usage of acoustic screens applied for noise reduction it is required to carry out theoretical and experimental assessment.
4) To present theoretical assessment it is required to possess the characteristics of the intended noises to be reduced as well as to have the requirements for screens to be applied together with geometric values.
5) In determining the efficiency of the chosen screens here is proposed the classical *Fresnel-Kirchhoff approximate theory.*
6) In analyzing the acoustic characteristics of a screen it is required to isolate and absorb the sound energy approaching the screens; acoustic characteristics depend on the materials and dimensions that have been selected for the screens.
7) While making use of the qualities of the materials for screens and the shapes of the structures it has been determined that screen sound isolation and absorption depend on the separate characteristics of acoustics of single elements used here, such as rigidity (in changing the shape of the element), porosity and etc,.
8) It has been determined that in applying cone type elements it is possible significantly to improve screen sound isolation characteristics in particular at low frequencies when the screen mass (weight) is not increased.
9) Here is proposed a new design of a screen with cone type elements, the advantage of which have been proved theoretically and partly implemented in practice.

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