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RAIL TRAFFIC NOISE AND VIBRATION MITIGATION MEASURES IN URBAN AREAS

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Preliminary notes

Today, reduction of rail traffic noise and vibration is a widely used concept for improving the life standard in vicinity of railway lines. Elevated levels of noise and vibration are the main factors of dissatisfaction, especially in urban areas. The paper reviews the effectiveness of noise and vibration mitigation measures applied to the network of European railway systems. These measures could also be applied to Croatian railways network where the issue of noise and vibration has not been addressed so far. Also, the paper presents research results of the application of several mitigation measures performed by the Department for Transportation at the Faculty of Civil Engineering, aimed at increasing the impact definition of their performance in local conditions.

Keywords: *mitigation measures, noise, rail track, rail traffic, rail vehicles, urban areas, vibrations*

Mjere za smanjenje buke i vibracija od tračničkog prometa u urbanim sredinama

Prethodno priopćenje

Smanjenje buke i vibracija od tračničkog prometa pojmovi su koji se danas najviše koriste vezano za ugodno življenje u područjima smještenih neposredno uz željezničke pruge. Povišene razine buke i vibracija glavni su faktor nezadovoljstva, posebno stanovnika urbanih sredina. U radu je dan pregled i učinak mjera za smanjenje buke i vibracija koje se u najvećoj mjeri primjenjuju na mreži europskih tračničkih sustava, a koje bi se uvelike mogla primijeniti i na mreži hrvatskih željeznica, gdje se problemu buke i vibracija do sada nije pridavala velika pažnja. Također, prikazani su rezultati istraživanja učinka primjene nekolicine mjera provedenih od strane Zavoda za prometnice Građevinskog fakulteta u cilju preciznijeg definiranja njihovog učinka u lokalnim uvjetima.

Ključne riječi: *buka, kolosijek, mjere za smanjenje, tračnički promet, tračnička vozila, urbane sredine, vibracije*

1 Introduction

Studies of noise and vibrations caused by traffic operations on tracks, as a part of analysis of rail traffic impact on the environment, are often considered as one and the same discipline because both phenomena have many common physical characteristics. They are both analyzed as a wave phenomenon: noise is defined as sound waves propagating through the air, while vibrations travel through the ground also in the form of waves. They are both result of oscillations (vibrations) of wheels and rails during vehicles rolling on track i.e. dynamic forces arising due to wheel-rail interface roughness. At high frequencies, this excitation energy expands through the air in the form of sound waves (noise), whereas lower frequency waves transmit from the rails to the lower parts of the track structure, through the ground and to the objects in the ground (Fig. 1). Roughly speaking, vibrations and structure-born noise occur in the frequency range 0÷100 Hz and noise 30-2000 Hz [1].

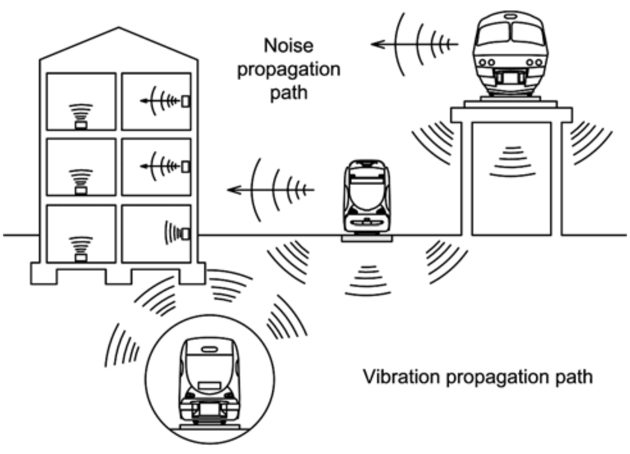

Figure 1 Rail traffic noise and vibrations

2 Noise and vibration mitigation measures

There are four main groups of rail traffic noise and vibration mitigation measures:
- reduction at source,
- reduction of propagation,
- isolation of receiver,
- economic measures and regulations.

The first group represents the so-called primary measures, while the other three groups are considered to be secondary measures of protection against rail noise and vibration. This paper will consider only the first two measures that are primarily related to the track and rail vehicles.

2.1 Reducing noise and vibrations at source

Reduction of noise and vibration at source can be achieved by:
- increasing the elasticity of the track superstructure,
- eliminating the running surface discontinuities,
- regular maintenance of the rail running surface,
- regular wheel re-profiling,
- selecting the appropriate type of rail vehicle,
- reducing the speed of rail vehicles.

2.1.1 Railway track superstructure type

Optimal measure for reducing the formation and propagation of vibration is the correct choice of railway track superstructure elements (fastenings, sleepers, ballast). Increase of the flexibility of these elements, raises their ability to damp (absorb) vibrations generated at wheel-rail interface.

Foreign studies showed that, compared with a rigid fastening systems, use of resilient fastening systems provides noise reduction from 3 to 6 dB(A) [2]. The results of railway traffic noise research in Zagreb, conducted by the Department for Transportation, at nine locations along the lines of the Pan-European Corridor X that passes through settlements Retkovec and Gajnice, showed that the use of resilient rail fastenings reduces noise by, in average, 2 dB(A) (Fig. 2) [3].

Application of high-resilience fastening systems (Fig. 3, [4]), in which elastic elements supporting the rail at the web prevent direct contact between the rail foot and sleeper, allows significantly greater vertical deflection of the rails under operation. Low vertical dynamic stiffness of the entire system reduces vibrations by 5 to 10 dB at frequencies above 30 Hz [5].

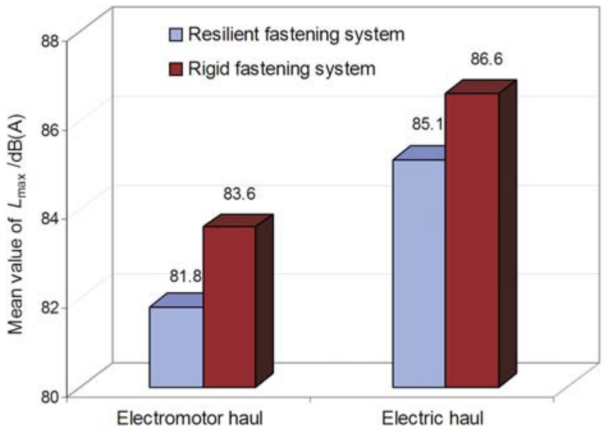

Figure 2 Influence of rail fastening system and haul type on noise levels

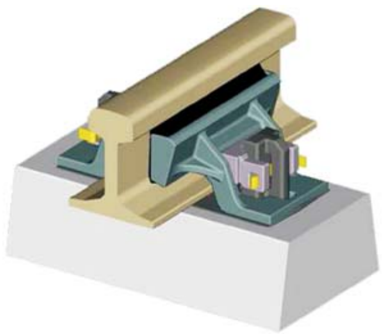

Figure 3 High-resilience fastening system

Figure 4 Resilient pre-loaded fastening system

Pre-loaded fixation systems are discrete rail fasteners with a highly resilient under base-plate pad (Fig. 4, [4]), that ensure vibration isolation by 20 dB in frequency range 25÷120 Hz [6]. The resilient pad is pre-compressed by specially designed springs with a load which is about 80 % of the normal static load on the fastener during vehicle passage [7]. The pre-loading spring is completely unloaded during vehicle passage and hence there is no vibration transmission through this spring to the lower parts of construction.

Discretely or continuously embedded rail systems can only be used in ballastless tracks. These systems are constructed by laying the rail in a longitudinal recess created in the concrete base structure which is then either filled by pouring out elastic embedding material (at the bridges steel moulds are applied) or by installation of prefabricated rubber parts around the rail web. Embedding the rail in elastic material reduces the possibility of rail vibration and, thus, reduces noise up to 10 dB(A) [8]. The bedding material not only elastically supports and fastens the rail but also insulates its web. Foreign research and experience in the use of these fastening systems showed that the elimination of metal-to-metal contact provides an average vibration reduction up to 8 dB in frequency range 5÷400 Hz [9]. The results obtained by measuring noise and vibrations on the Zagreb tram tracks, at the intersection of Draskovic and Jurisic streets, fitted with standard discrete rail fixations to concrete slab (before track reconstruction), and after reconstruction (i.e. after implementation of continuously embedded rails), showed vibration reduction between 12,9 and 18,6 dB, depending on the tram vehicle type. The mean value of maximum measured noise levels after the reconstruction, compared to noise measurements results obtained before reconstruction, is lower by 1,5 to 3 dB(A) [10].

Figure 5 Infusion of elastomeric material between discrete supports

Figure 6 Continuously supported and embedded rail

Rail dampers (Fig. 8, [11]), prefabricated elements that can be glued or clipped on to the rail web, increase the total weight of the rail which adversely affects its ability to vibrate. Use of rail dampers reduces the displacement of the vibration waves along the rail, followed by reduced vibrating length of the rail, and ending in reduced noise. Rail

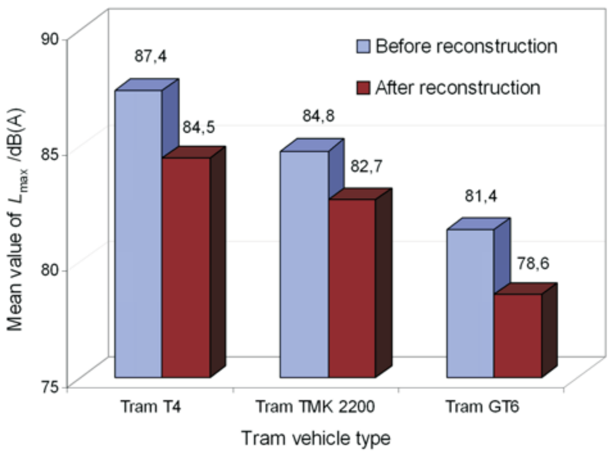

Figure 7 Noise levels at the intersection of Draskoviceva and Jurisiceva street in Zagreb before and after reconstruction

dampers consist of steel components, which act like springs under the influence of vibrations, and elastomeric material that absorbs the energy of rail (springs) oscillations. Studies conducted by German (DB) and French (SNCF) Railways, at the rail track sections with rail dampers installed, showed a reduction in noise up to 6 dB(A) and vibration up to 9 dB [12].

Figure 8 Rail vibration dampers

Although the installation of concrete sleepers, as compared to wooden sleepers, has many economical advantages (simpler installation, greater durability, lower maintenance and operation costs) concrete sleepers have less vibration damping capacity due to their higher rigidity. Results of railway traffic noise research, preformed by Department for Transportation on several locations in Zagreb, showed that the railway tracks with wooden sleepers, depending on the type of passing train, are "quieter" than tracks with concrete sleepers for about 1÷2 dB(A) [3]. Foreign studies indicate that the installation of wooden sleepers enables vibration reduction by 5 dB [5].

Vibration attenuation can be achieved either by placing the elastomeric pad between the sleeper and ballast bed or concrete slab in case of a ballastless track. This elastomeric pad is usually composed of two layers of different material: the upper layer attached to the bottom surface of the sleeper is made from the viscoelastic rubber with high vibration damping ability and the lower layer is coarse geotextile that serves to prevent possible upper layer damage from impressing of crushed ballast material. Foreign practice has shown that the greatest effect of these under sleeper pads on vibration reduction can be achieved at vibration frequencies

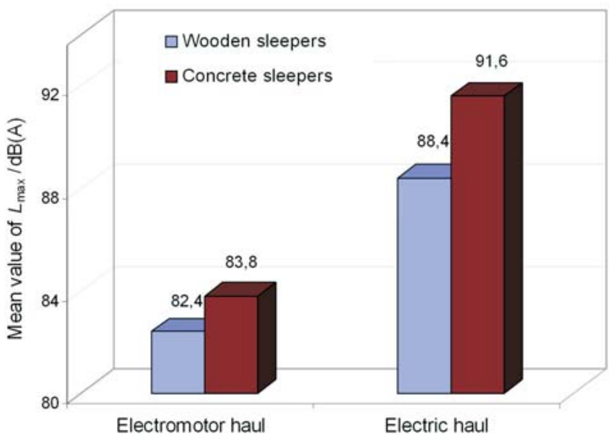

Figure 9 Influence of sleeper and haul type on noise levels

greater than 63 Hz, at which it is possible to achieve vibration reduction by 8 to 15 dB (up to 30 % less vibration) and air transmitted noise reduction by up to 3 dB(A) [13]. Additional lining the sides of the sleeper with rubber material (so called "booted" sleepers) can reduce the vibration transmission for up to 20 dB at frequencies above 63 Hz [14].

The positive experiences of European railway administrations in the application of elastic under sleeper pads inspired the Department for Transportation at Zagreb Faculty of Civil Engineering to conduct its own research of the impact of under sleeper pad on the vibration propagation. Analyses were conducted at the testing site on four types of track structures. These structures differed by the elasticity of contact between sleepers and structures lower layer:

- "TYPE A"– sleeper without under sleeper pad,
- "TYPE B"– sleeper with under sleeper pad, and by the type of sleepers bedding:
- "Variant 1"– ballastless track,
- "Variant 2"– ballast track (Figures 10, 11 and 12).

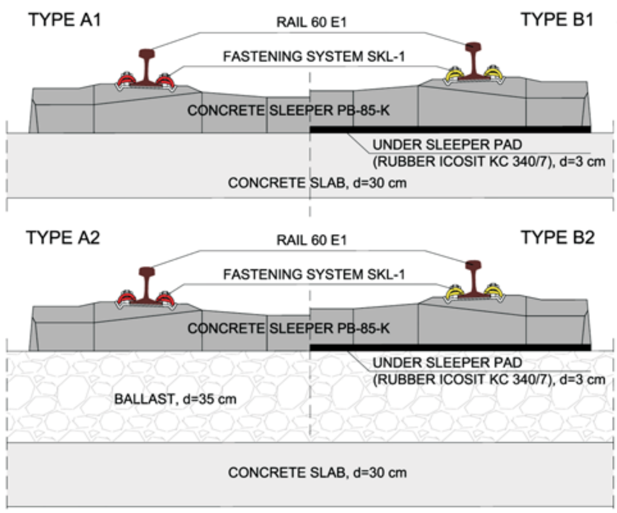

Figure 10 Testing constructions (A1, B1, A2, B2)

Concrete slab vibrations were measured by triaxial accelerometer during the effect of impact load which simulates the wheel-rail contact forces due to irregularities on running surface. Impact was achieved by lowering the weight of 3,66 kg (36,6 N) on the rail head, just above the fastenings. Tests have shown that the use of resilient under sleeper pads causes an average reduction of vibration by

Figure 11 Testing site 1

Figure 12 Testing site 2

16 dB. Comparison of difference in vibration values between the type A1 and B1 structures showed that the use of under sleeper pads can cause a small increase in the intensity of the low frequency vibrations [15]. This result fully concurs with previous research and experience of European railway administrations, whereby it is necessary to emphasize that the mechanism of increased low frequency vibrations in the case of under sleeper pads installation has not yet been elucidated.

In terms of vibration damping, track structures with ballast bed are better than the track structures on special reinforced concrete slabs (so-called slab tracks). Studies have shown that the classical ballast track is up to 3÷5 dB(A) "quieter" than the ballastless track [2]. The reason is greater noise absorption properties that ballast bed has compared with a concrete slab. Tests preformed by the Department for Transportation at the Zagreb Faculty of Civil Engineering, conducted as part of the previously described research of the effects of under sleeper pads, showed that low-frequency vibrations on the tracks with ballast bed are typically up to 30 times lower than vibrations on slab tracks [15]. Further reduction of the vibration propagation can be achieved by increasing the height of ballast bed. Measurements conducted by the German Railways (DB) showed that increase in the ballast bed height from the usual 30 cm to 75 cm can reduce the vibrations by 6 dB at frequencies lower than 10 Hz [2], but there is a question of technical and economic feasibility of applying such measure.

Ballast mats (Fig. 13, [6]) isolate the track substructure (subgrade or bearing structure) from the vibrations that occur at wheel-rail contact and then propagate through lower elements of track superstructure. In general, this insulating layer should be placed on a concrete slab or foundation in order to be effective, and not directly to the subsoil. Use of ballast mats can reduce vibrations by 10 to 15 dB at frequencies between 25 and 30 Hz [5], and by 8 to 18 dB at frequencies above 63 Hz [14].

Figure 13 Sub-ballast mat

Construction of the rail track without ballast bed, on reinforced concrete slabs, is a common type of track construction in tunnels and in urban areas. The main disadvantage of this type of track construction, compared with tracks laid in ballast bed, is its greater rigidity, which results in increased vibrations. The basic principle of reducing vibrations in these structures is to increase the mass, to elastically support and reduce the natural frequency of the track superstructure [1]. Special types of the slab tracks made upon this principle are so-called "mass-spring systems", which consist of a concrete slab placed on the flexible bearings. In such systems, which are also called "floating slab tracks", the rails are either directly fastened to the upper concrete slab or this upper slab can serve as a "trough" for ballast material. The upper slab lays on resilient pads (rubber or elastomer) that can be arranged discretely, linearly or full-surface. In order to maximize the effect of vibrations reduction, such "floating slab tracks" should have very low natural frequency. Studies have shown that the natural frequency of such structures lies between 8 and 12 Hz, depending on the material used and the total weight of the structure. The application of such structures allows the vibration reduction by 10 dB (16 Hz) or by 25 dB (125 Hz) [14]. Examples of this mitigation measure on tram tracks in Zagreb are present in Horvacanska street where the elastomeric pad is incorporated between the continuously reinforced concrete slab track and ceiling plate of pedestrian underpasses (Fig. 14) and at the Kvaternik square where there is an asphalt layer between the slab track and the ceiling plate of underground garage (Fig. 15) [10].

Figure 14 Horvacanska street (Zagreb, 2000)

Another version of this "floating slab track" consists of the slab with the rails supported on discretely situated steel springs that are fixed on the base plate (Fig. 16 [16]).

Figure 15 Kvaternik square (Zagreb, 2007)

Figure 16 Floating slab track on springs

Vibration measurements preformed on a floating track with ballast bed and spacing of the springs in 3,7 m showed that the system has 90 % vibration isolation efficiency and the transmission loss was about 40 dB between 10 to 100 Hz frequency [9].

2.1.2 The elimination of discontinuities at the rail running surface

In continuously welded tracks, wheel impact at the rail joint (Fig. 17, [17]) is eliminated allowing vibration reduction for up to 5 dB [1].

Figure 17 Damaged insulating joint

A large percentage of rail traffic noise and vibration is caused by wheel impacts at the special trackwork for switches and crossings. This impact occurs because of the gap between the running rails and frog and can cause an increase in noise levels from up to 6 to 10 dB(A) [5]. Noise and vibration due to wheel impact at switches can be controlled by regular maintenance of the frog point and wing rails. Another approach is to use special devices at turnouts and crossings, special "frogs," that incorporate mechanisms to close the gaps between running rails (frogs with spring-loaded mechanisms and frogs with movable points).

2.1.3 Rail running surface maintenance

German research showed a 15 dB(A) sound level difference between a rough, corrugated rail and as smooth as possible rail surface. Hence, large noise reductions can be achieved by introducing a track surveillance program aiming at keeping the rail surface smooth [18]. Effective maintenance programs are also essential for controlling ground-borne vibration. When the rail surfaces are allowed to degrade, the vibration levels can increase by as much as 20 dB compared to a new or well-maintained system [5].

The levels of noise and vibration caused by wheel rolling on corrugated rail running surface depend on the size of irregularities (amplitude and wavelength). Regular rail grinding is necessary for the removal of corrugated rail wear, largely responsible for rail traffic humming noise, and also removal of irregularities at rail welds responsible for the occurrence of noise and vibration due to wheel impacts.

Figure 18 Damaged rail weld on tram track in Zagreb

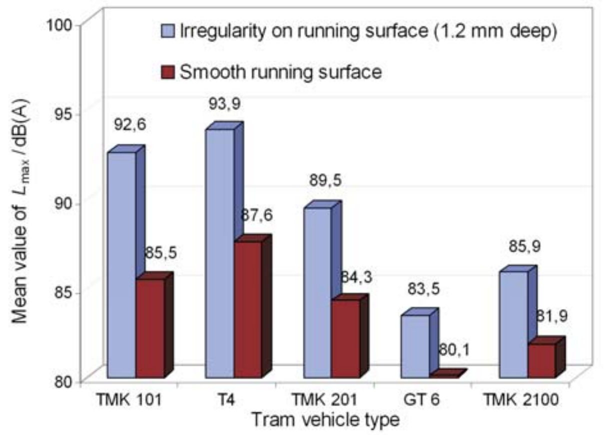

Figure 19 Mean value of maximum noise depending on the rail running surface smoothness and tram type

From the analysis of weld geometry impact on noise levels [19], it was found that in the case of irregularities on tram tracks where the vertical deviation is greater than 0,33 mm, the noise level increased from 1,5 to 10 dB(A) (depending on the vehicles type and driving speed) in comparison to the smooth running surface (Fig. 19).

Increasing the hardness of the rail head slows down the formation of the corrugations at rail running surface i.e. the reduction of noise and vibration is achieved. This increase in rail head hardness can be achieved by treating of the rail head with heat during rail production (Fig. 20, [20]) or in situ by rail head surfacing (Fig. 21) where grooves are ground into the rail head, filled out with a hard electrode and surface-ground [21].

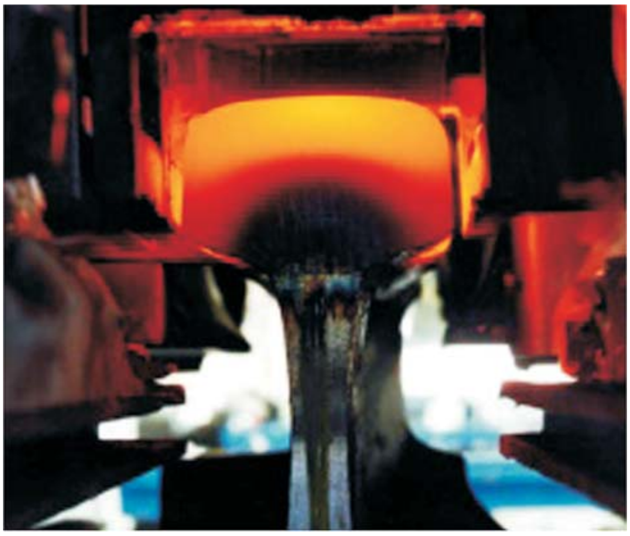

Figure 20 Rail head hardening – thermal treatment during production

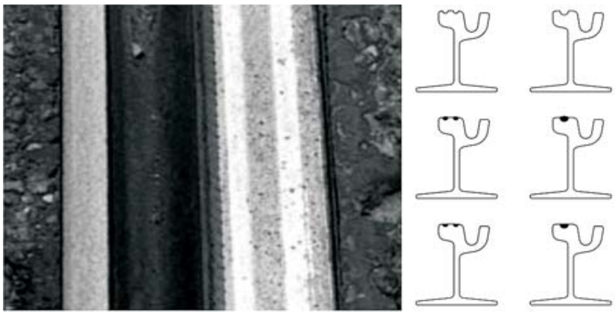

Figure 21 Rail head hardening –in situ rail head surfacing

Squeal noise that occurs due to abrasion of the wheel on the outer rail head in small radius curves (R < 400 m) can be reduced by lubricating rails or wheel flange. The maximum squeal noise level reduction is not as important as elimination or reduction of the duration or occurrence of squeal. A reduction of the occurrence or duration of wheel squeal by a factor of two will reduce wayside energy equivalent noise levels by 3 dB(A), even though the maximum level is unaffected [2].

2.1.4 Rail vehicle (wheel) type and maintenance

Wheel maintenance by grinding is necessary to remove the irregularities on wheel running surface (mostly wheel flats) and provide required wheel profile. Compared to reprofiled, worn wheels increase vibration by 5 to 10 dB [5], while the wheel flats can cause additional vibration increase by 5 dB at frequencies above 60 Hz [1]. High quality wheel grinding (reprofiling) program ensures the reduction of noise levels in the range of 5 to 10 dB(A) [5].

Traditionally, freight trains have been equipped with cast iron block brakes whereas passenger trains are equipped with disc brakes. Experience has shown that cast iron block brakes, already after a short period of usage, cause wheel corrugation that generates high frequency noise. Use of the disc brakes can reduce noise levels by 10 to 15 dB(A) [18].

An alternative to the more complicated and expensive disc brakes is to replace the cast iron blocks with sinter metal or composite blocks. Application of composite block brakes enables reduction of wheel damage and noise emitted during braking. Research conducted in 2005 in the framework of a working group funded by the UIC (WG - Rail Freight Noise Abatement) showed that the use of composite brakes reduces noise levels by 8 to 10 dB(A). Composite block brakes were applied in 2006 to electric train that rides on the Zagreb-Moravice-Zagreb line. Tests have shown a satisfactory quality of the built-in braking system.

Resilient wheels (Fig. 22) serve to reduce rolling noise. A typical reduction is 3 do 6 dB(A) on tangent track. This measure is more effective in eliminating wheel squeal on tight turns where reductions of 10 to 20 dB(A) for high-frequency squeal noise are typical [5].

Damped wheels (Fig. 23), like resilient wheels, serve to reduce rolling noise. This measure involves attaching vibration absorbers to standard steel wheels. A typical noise reduction is 4 to 8 dB(A) on tangent track. Damping is more effective in eliminating wheel squeal on tight turns where reductions of 5 to 15 dB(A) for high-frequency squeal noise are typical [5].

Figure 22 Resilient wheels (rubber pads installation)

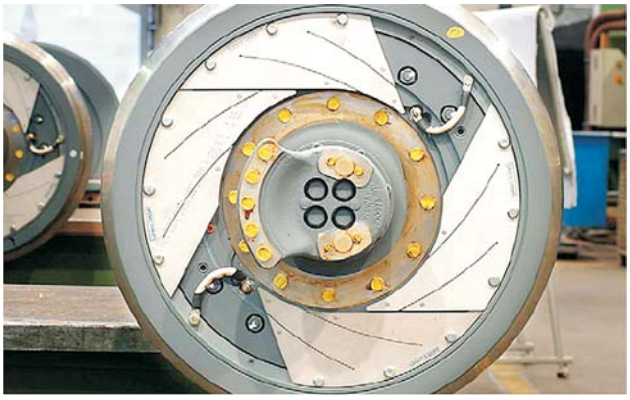

Figure 23 Damped wheels

2.1.5 Reducing the rail vehicle speed

Very important role in noise and vibration propagation mitigation has not only construction of permanent way and track substructure, but also type and speed of the rail vehicles. Reducing the train speed by a factor of two will reduce vibration levels approximately by 6 dB [5].

During the investigation of rail traffic noise at the Western Railway Station in Zagreb, maximum noise levels were recorded during the passage of different types of railway vehicles regarding type of haul (diesel or electric), speed (with or without stopping at the Station) and transport type (passenger or freight). From the measurement results it was concluded that the operation of local diesel passenger trains and transit freight trains generated noise to 15 dB(A) higher than the noise of the local electric passenger trains that stopped at the station [22]. Also, at very low train speeds (i.e. starting the train from the station) accelerating diesel locomotive has a major impact on the overall noise level. Measurements conducted at the settlement Retkovec (Zagreb), located next to a railway line Zagreb-Vinkovci, showed that at low train speeds (about 5 km/h) noise levels are 3 to 7 dB(A) lower than in the case of the train passing at operating speed [3].

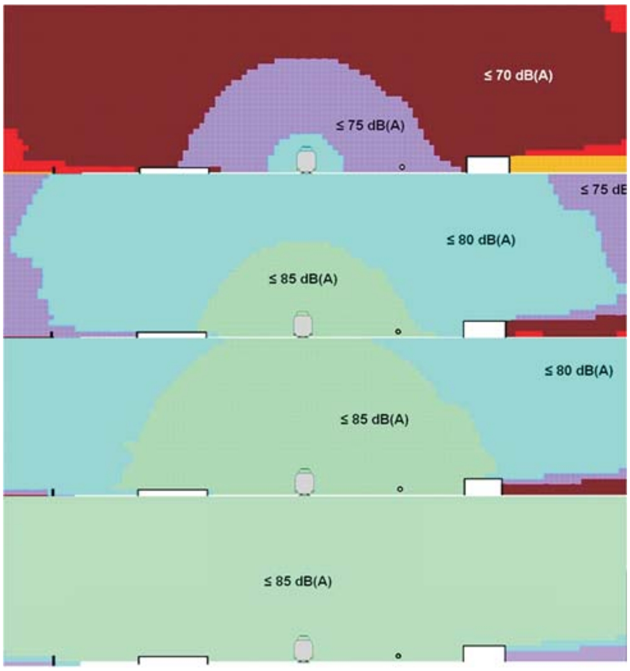

Figure 24 Rail traffic noise at Zagreb Western Railway Station

2.2 Noise and vibration propagation mitigation

Increasing the distance between the track and the receiver is one of the most effective measures of noise and vibration reduction, but only appropriate in cases where the cost of land purchase is less than the estimated cost of the implementation of other mitigation measures. At a distance of 500 m from the rail track people no longer perceive the rail traffic vibrations [23], while the air borne noise decreases by about 20 dB(A) [24].

Implementation of noise protection barriers is the most effective measure of noise reduction at the receiver, after all possibilities of noise reduction at source have been carried out. Barriers enable the reduction of noise at the observed point of immission in the range from 5 to 15 dB(A), depending on the height and length of the barrier, material from which it is constructed and the distance between the source and receiver [5].

Use of trenches to control ground-borne vibration is analogous to controlling airborne noise with sound barriers. A trench can be a practical method for controlling rail traffic vibration from at-grade track. Studies have shown that the reduction in vibration at frequencies of 30 Hz requires a minimum trench depth of 4,5 m [5].

Figure 25 Noise protection barrier

By performing various methods of soil stiffening (lime modification, lime injection and jet grouting) it is possible to get soil with a larger vibration absorption capacity. Research has shown that reducing the coherence of the soil allows reducing vibration by 14 dB within the frequency of 4 to 32 Hz [14].

A convenient alternative solution to reduce the propagation of vibration in urban areas, where performance of trenches is impossible due to the existing development, is the performance of the underground barriers near the rail track. Such barriers are performed in situ, by mixing existing soil with live lime or cement, in the form of pillars with diameter from 0,5 to 1,0 m. The depth of the barriers depends on the frequency of vibration that needs to be reduced. The lower the frequency of vibration, the greater is the needed depth of such barriers (depth of the barrier needed to reduce the vibration for about 25 % ranges from 10 to 15 m) [10].

By situating rail tracks in a cut of minimum depth 7,5 m, a reduction of noise at the point of imission for up to 15 dB(A) can be achieved. By situating rail tracks on an embankment, a reduction of noise at the point of imission for up to 5 dB(A) can be achieved, if the height of the embankment is at least 3 m [25].

By placing the rail track in tunnels, the greatest effect of noise and vibration reduction can be achieved. With additional application of specially designed tracks in tunnels, such as "floating slab tracks", it is possible to achieve vibration reduction for up to 40 dB [9]. This measure is rarely used exclusively to reduce rail traffic noise and vibration, since the cost of tunnel construction, maintenance, lighting and ventilation is very high. Therefore, the reasons for lowering the rail tracks in urban areas in the underground are, in the first place, operational in nature, which can be confirmed by the example of the town of Split. During 70's of the last century, single track divided the town into two parts causing traffic jams on level crossings and creating obstacles for normal life of the inhabitants. Therefore, the plan was made for cutting and covering of railway and for substituting single track on ground with electrificated double track in tunnel. By completion of the tunnel in 1979, both traffic congestion and pollution of the surrounding residential areas by rail traffic noise were completely eliminated [26].

3 Effect of noise and vibration mitigation measures

The effect of individual measures for rail traffic noise and vibration mitigation (measures for their reduction at source and also reduction of their propagation) is shown in Tab. 1. The data indicate that the measures relating to the application of the appropriate type of track construction, regular track and rail vehicle maintenance, the application of the appropriate type of vehicle and removal of the discontinuities on tracks could certainly greatly contribute to rail traffic noise and vibration reduction. By implementing changes in the noise and vibration propagation path (by constructing barriers and placing tracks in tunnels) the greatest effect of noise and vibration reduction can be achieved. The main problems with such interventions are the high construction costs and lack of space for their positioning in densely built urban areas.

In terms of reducing vibration at the source, a very effective measure is the installation of elastomeric pads under track construction (under sleepers in case of conventional ballast bed track or below the concrete slabs in case of modern slab tracks). When observing noise problem, the most effective mitigation measure would be elastically embedding the rails. Also, great benefit of these measures is that they can rather easily be implemented during regular maintenance or reconstruction of rail tracks.

Foreign experiences and local research have shown that the most significant reduction of noise and vibration from rail traffic can be achieved in a relatively simple way - by introducing a quality track inspection and maintenance program to ensure smooth and continuous rail running surface.

Table 1 Effect of noise and vibration mitigation measures

Mitigation measure	Noise reduction /dB(A)	Vibration reduction /dB
Reduction at source – permanent way		
Resilient rail fastenings	3 ÷ 6	5 ÷ 10 (20)
Embedded rail system	3 ÷ 10	8 ÷ 18
Rail dampers	5 ÷ 6	7 ÷ 9
Wooden sleepers	1 ÷ 2	3 ÷ 5
Under sleeper pads	0 ÷ 3	8 ÷ 15
Ballast bed height increase	3 ÷ 5	0 ÷ 6
Ballast mats	8 ÷ 18	10 ÷ 15
Elimination of the rail running surface discontinuities	6 ÷ 10	0 ÷ 5
Maintaining smooth rail running surface	10 ÷ 15	10 ÷ 20
Reduction at source – rail vehicles		
Wheel re-profiling	5 ÷ 10	5 ÷ 10
Reduction of speed	3 ÷ 7 (10)	3 ÷ 6
Disc brakes	10 ÷ 15	-
Composite brakes	8 ÷ 10	-
Resilient wheels	3 ÷ 20	3 ÷ 4
Propagation reduction		
Barriers	10 ÷ 15	0 ÷ 14
Tunnels	0 ÷ 30	10 ÷ 40

4 Conclusion

The problem of rail traffic noise and vibration occurrence, propagation and the effect they have on people and rigid structures is very complex due to the large number of influential parameters and is still not fully understood, despite numerous researches. The increased intensity of rail traffic noise and vibration could become a common environmental problem in the near future, due to the continuous need to increase the freight trains weight, passenger trains operational speed and the railway lines capacity, and also the lack of free space in urban areas which results in placing new business and residential facilities in the immediate vicinity of the railway. Rail traffic noise and vibration problem are particularly pronounced in cities with intense tram traffic mainly due to a very small distance between tram tracks and the surrounding buildings. This fact limits the possibilities for implementation of noise and vibration propagation mitigation measures.

To answer the question which measure of railway traffic noise and vibration mitigation could be most effectively applied, it is necessary to register the current state at the specific location, analyze the applicability of certain number of measures and then adopt the optimal one from the economic and engineering point of view. Systematic investigations require substantial financial resources, which is why they are, in Croatia, still carried out only in individual studies of limited scope. Until today, noise protection was considered and implemented only for the Croatian highways, while the protection from the railway noise was completely neglected. Also, although the problem of rail traffic vibration is recognized by the profession, to date there are no adopted standards or regulations concerning to the problem of vibration from railway traffic.

It should be noted that in some European countries researches of rail traffic noise and vibration began in the 70' and 80' of the last century, and have regularly been financed from either the state budget or the budget of each municipal government. Such research was funded in France with 2,7 million € (1971÷1982), in Germany with about 4 million € (1978÷1983) and in UK with around 6,5 million € (1989÷1995). Today, Europe continues to steadily and rapidly conduct research in the field of rail traffic noise and vibration – there is a research project called Innovation Program Noise Road Traffic in preparation, launched in the Netherlands, which was initiated by the Ministry of Transport and Ministry of Environmental Protection. The project's budget is 50 million € with the following objectives: reducing the number of objects that are exposed to noise levels > 70 dB(A) for 100 %, noise levels > 65 dB(A) for 90 % and noise levels > 60 dB(A) for 50 %, until year 2030.

From described foreign experiences regarding the implementation and effectiveness of certain noise and vibration mitigation measures, it can be concluded that their implementation during the construction or reconstruction of modern rail and/or tram track provides significant improvements in terms of reducing the dynamic effects on the track responsible for the emergence of these extremely adverse effects. All the conclusions about the advantages and disadvantages of the described mitigation measures have not yet been adopted at the European level, but so far a positive experience in their application shows that its implementation should become a common practice, especially on new tracks for high speed railways and urban rail systems.

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