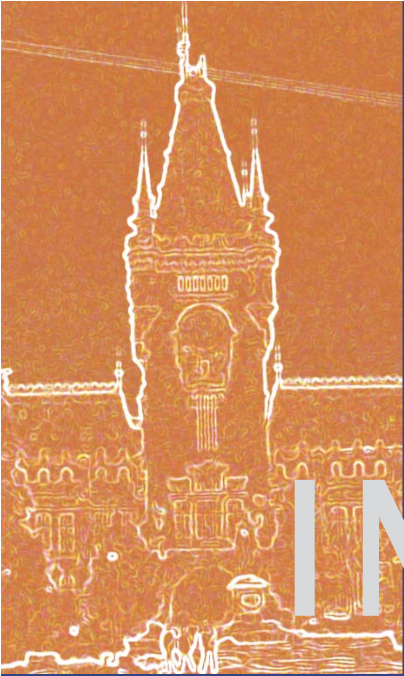

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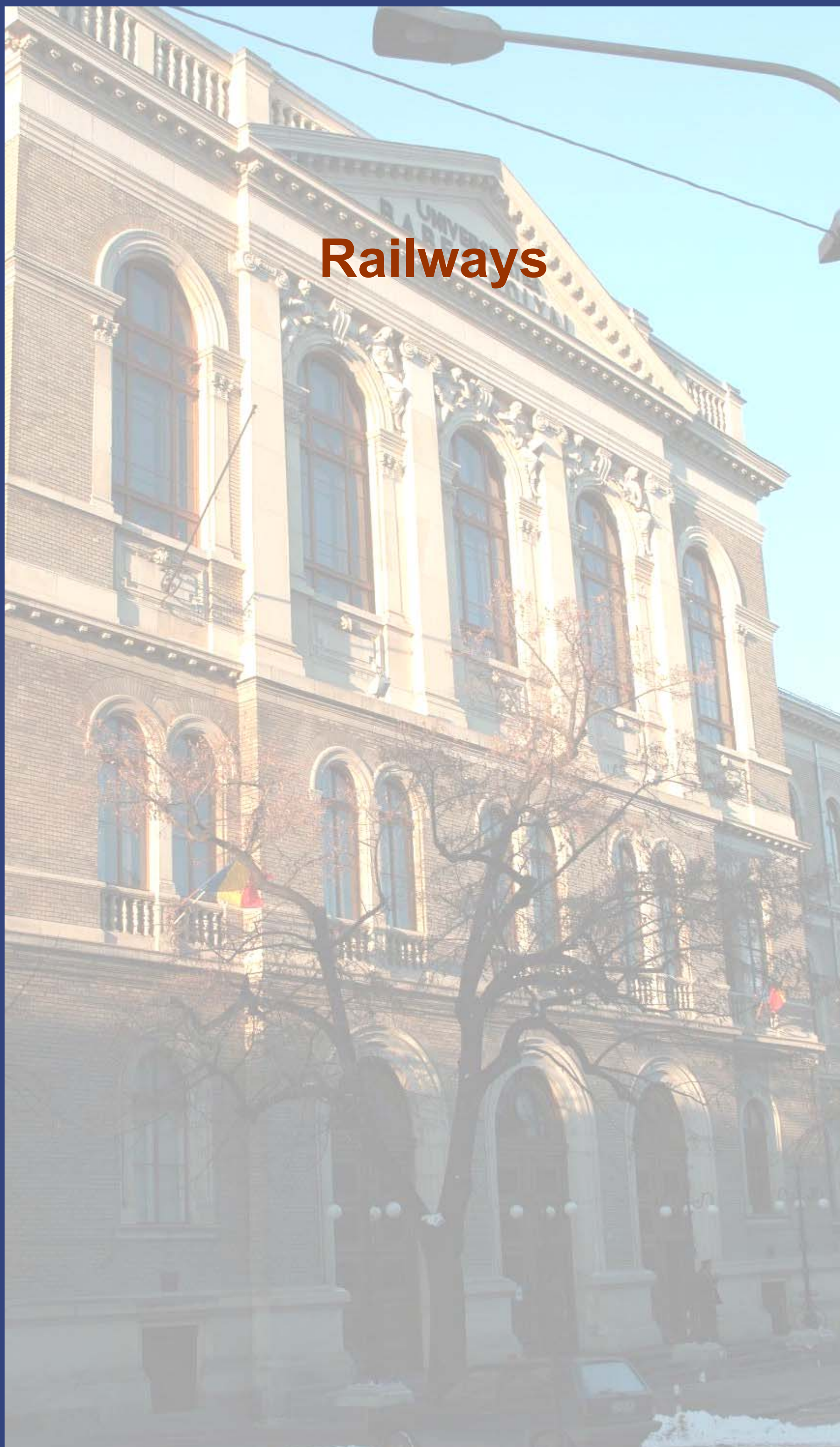

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Mitigation of railway roise and vibration concentrating on the "reducing at source" methods

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Summary

Transportation systems are basically linked with a wide range of environmental considerations. Definitely noise is the most perceptible and measurable nuisance caused by railway transport. Appraisals indicate that more than 50% of the European population is continuously exposed to noise levels above 55 dB(A) and 16% over 65 dB(A). Principally transport within railway transport is responsible for the high and permanent noise level. One of the greatest technological challenges of our times is noise attenuation and vibration damping. In the following paper I introduce briefly the causes of railway noise and vibration. Than I summarize those active and passive noise reduction and vibration mitigation technologies that are in practice nowadays. Most of the methods are based on track intervention whether it is a regular maintaining of the track or reconstuction.

1. Introduction

Transportation systems are basically linked with a wide range of environmental considerations. Although railway is an environmentally friendly mode of transport for people living or working alongside the railway, it can be also an annoying source of noise. In case of railway transport definitely noise and vibration is the most perceptible and measurable nuisance. One of the greatest technological challenges of our times is noise attenuation and vibration damping. Several methods are applied nowadays but when noise and vibration problems are eliminated at source not only individual structures or a part of the surrounding but the entire neighbourhood is protected. In the following study I deal briefly with the causes of railway noise and vibration and introduce in detail the "reduction at source" methods with special consideration of the railway track interventions.

KEYWORDS: railway transport, noise, vibration, mitigation

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2. Causes of railway noise and vibration

Train noise and vibration is generated by:

- Vehicles
- Wheel/rail contact
- Aerodynamic effects
- Vibrating structures
- Other railway noises

2.1. Vehicles

Locomotive noise includes not only engine noise that is dominant mostly in case of diesel locomotives during accelerating, maintaining top speed or working up gradients, but that of auxiliary equipment, such as air compressors, cooling fans, heating or air conditioning equipments and pantograph. *Passenger coaches* cause less noise as their design such as suspension, boogies, wheels, isolations aiming better, more comfortable ride. No such reasons exist in the design of *goods wagons*, where loose joints, rigid suspension cause more vibration also at audible frequencies. Some of the *track building* or *maintaining machines* have really great noise level, but this effect is considered as temporary nuisance.

2.2.Wheel/rail contact noise

The level of the wheel/rail contact or in other words the rolling noise depends on several factors. It is principally related to velocity but highly depends on the condition and type of the rails and wheels as well as the axle load, the brakes, the suspension and the boogies of the vehicle.

High rail profiles as their vibrating web is higher emit more noise. The roughness of the rail and wheel surface can extremely increase the noise level. Typical roughness are rail corrugation and "wheel flat", both are the result of the action of the iron tread brakes. Beside the above-mentioned problems tread brakes resulting higher noise level during action, meanwhile the disc brakes are more favourable. The design of the brake, the wheel, the suspension and the isolation of passenger coaches aim smooth ride and thus lower rolling noise level. But such aspects are left out of consideration in the design of goods wagons all over the world.

Train passing over opened fish-plated rail joints increases the noise level that is not existing on continuously welded tracks. Extended friction between wheel and rail in tight curves can also cause a high frequency, sharp, squealing noise.

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2.3. Aerodynamic effects

Aerodynamic noise becomes significant over high speeds that can be eliminated by the design of the vehicles, such as streamlined locomotives or special cover for pantographs.

2.4. Vibrating structures

Trains passing over bridges are vibrating the structure that is most significant on steel bridges where the track is fixed directly to the gilders. Vibration grows in tunnels where cross-sectional arrangement, soil type or ground water level can also influence the result.

2.5. Other railway noises

Additional to the noise of a passing train there are various other effects, such as the noise of horns, the air pressure as trains leave tunnels or pass under bridges, public announcement systems or electric substations.

3. Mitigation of Railway Noise and Vibration

The adverse effects of noise and vibration caused by railway traffic can be countered by different measures:

- to reduce them at source (active control),
- to attenuate their propagation (passive control), or
- to insulate the affected buildings (passive control).

Passive control techniques are extensively applied. To attenuate the propagation of noise barriers are erected. But by nowadays longer and longer ugly walls cause visual intrusion from the train and within the landscape, as well. Other form is the individual protection when people try to shield their houses from the ambient noise. In this case double-glazing of doors and windows, insulations of walls and other part of buildings is very typical.

The above-mentioned methods are effective and their application is needed but for the future attention must be given to controlling the noise at source. With choosing these technologies the aim is to prevent the development of noise and vibration or to suppress them at source as much as possible.

Reducing noise and vibration at source can be already started on the vehicles. The generated noise and vibration can be controlled and abated by the correct design of wheels, suspension and brakes and with the isolation of the under-carriage, although this cannot be expected in connection with goods wagons in the near future. The regular reprofiling of wheel flanges is a well-tried procedure meanwhile wheel damping seems no cost-effective solution.

In the following sections I introduce how noise and vibration can be 'reduced at source' by the correct design or maintenance of the railway track.

3.1. Optimisation of wheel/rail interface

One of the major sources of noise generated by a passing train is caused by the wheel and rail surface roughness. Typical problems of rails are shelling, top and side wear, plastic flow, dipped welds and corrugation. Neglecting rail maintenance not only causes premature change out due to its rapid deterioration, but it results uncomfortable ride and increased noise and vibration. To eliminate rail roughness grinding is proved to be sufficient solution.

According to measurements of German, French and Japanese Railway Company the rolling noise level on rails with shell-like roughness can be 6-14 dB higher than on track with new and perfect rails in the frequency interval 500-2000 Hz. It is also established that after the first appearance of this type of roughness the generated noise level increases with time. According to measurements on short corrugated rails it was realized that 10 km/h increase of speed results 2 dB extra noise. The main theoretical explanation of it is the collision of rolling wheels on corrugated rails.

In curves there are extra effects that generate more noise. One of them is rubbing between wheel and rail that causes a grating noise. The other effect is the slippage of wheel on rail producing a high-frequency squealing noise. The main idea of the wheel/rail contact area lubrication is to modify friction, inhibit rubbing and slippage and by the help of this to control wear, minimize the rate of wheel and rail corrugation and reduce noise and vibration.

Continuity of the rail is also very important that can be achieved by welded joints instead of fish-plated ones. The passing train on an opened rail joint especially if there is vertical step between the two rail-ends can result up to 5 dB increase because of the knock of the wheel.

Eliminating wheel rougness is also an important noise control. The knock of the flat wheels as it is verified by measurements can generate 3 dB(A) extra noise.

3.2. Noise and vibration reduction in ballasted tracks

The correct choice of permanent way structures is one of the major possibilities in noise reduction and vibration damping. Ballasted tracks have better performance than slab tracks in damping as the crushed stone bed absorbs noise and attenuate vibration. Further improvements in ballasted tracks can be achieved with insulating the sleepers or the ballast with elastic mats (**Fig. 1.**).

Figure 1: Elastic support of the sleepers or the ballast bed

3.3. Noise and vibration reduction in slab tracks

Ballastless tracks may produce minimum 10 dB(A) extra noise because the slab reverberates the rolling noise. In this case resilient fastenings or elastic pads with low stiffness give better isolation (***Figure 2.***). In resilient fastenings the highly elastic plates or pads under the rail substitute for the elasticity of the ballast bed, as well. But elasticity is limited because of safety considerations and on the other hand higher elasticity results greater deflection of the rail that increases the radiated noise. That is why the application of rail dampers are recommended in resilient tracks.

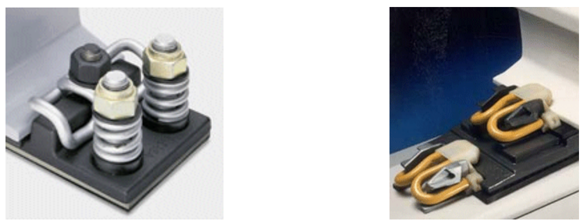

Figure 2. Spring fastenings with high vibration damping ability

Special solutions are the discretely or the continuously embedded rail systems where the bedding material not only elasticly supports and fastens the rail but also insulate its web (Fig. 3.). In these fastening systems the metal-to-metal contact is eliminated. A test section was built with a discretely embedded rail fastening (Fig. 3./left) on the slab track of the Budapest Metro. Measurement completed before and after installation proved that the average vibration reduction between 5-400 Hz was 8 dB.

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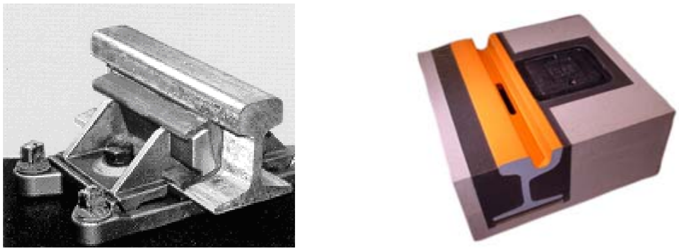

Figure 3: Elastomeric fastenings with high vibration damping ability

Special versions of slab tracks are the mass-spring-systems that consist of a floating slab with the rails mounted on them. Therefore these systems also named as floating track. The upper slab can be a trough for ballasted tracks, as well. In some versions the upper slab lays on resilient pads (rubber or elastomer) that can be arranged discretely, linearly or full surface (**Fig. 4.**). This arrangement depends on the resonant frequency of the structure. The heavy reinforced concrete slab with the track structure elements and the ballast (if exists) forms a great, dynamically active mass that reduce the trasmission of the dynamic effects of the passing trains to the base slab.

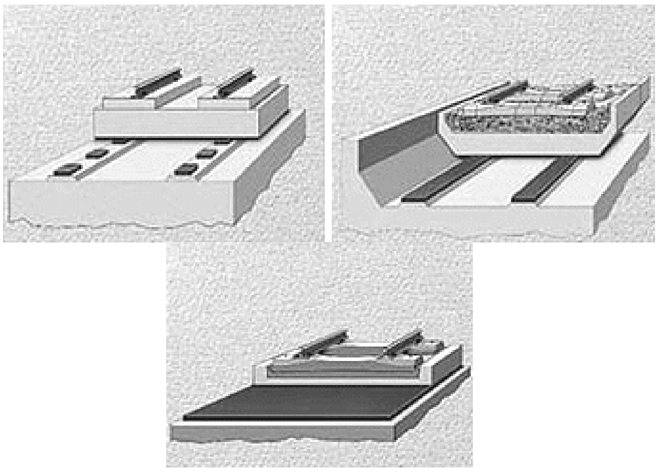

Figure 4: Floating track lays on resilient pads

In another version the slab with the rails is supported on discretely situated steel springs that are fixed on the base plate (**Fig. 5.**). Vibration measurements were completed on a floating track with ballast bed and spacing of the springs in 3.7 m. In this measurement the vibration was recorded on the top of the floating trough and on the base slab. The results proved that the system has 90% isolation

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efficiency and the transmission loss was about 40 dB between 10 to 100 Hz frequency.

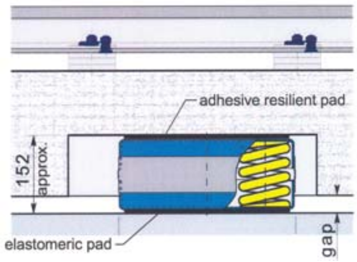

Figure 5: Floating track slab situated on springs

3.4. Reduction noise and vibration by rail insulation

Rail insulation is another possibility of noise reduction. Passing trains vibrate the rail. This vibration is transmitted to the air and cause noise. If the vibration of the rail is suppressed noise level can be decreased. Typically used solution is the rail tuner that is fixed on the mostly resonating cross-section of the rail. Rail web damper is a rubber cubic profile or a thin layer with high absorbing ability that is glued to the rail web (**Fig. 6.**)

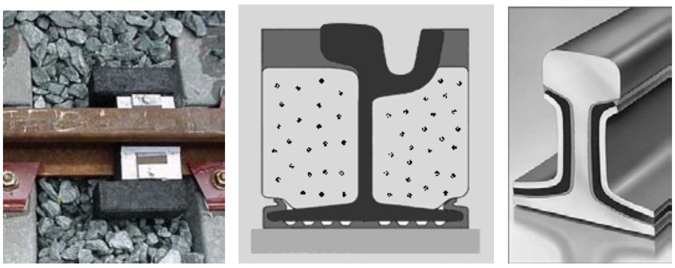

Figure 6: Rail tuner and rail web dampers

Short time ago I completed noise measurements on a rail that was covered with damper that was developed by a Hungarian company. The tests were carried out in laboratory on a piece of rail with and on another without insulation both are fastened in the same way on concrete sleeper. The aim of the tests was to compare the noise level and the frequency range of the insulated rail with that of the not insulated one under the same type of excitation. The decrease of noise level was about 5-8 dB due to the insulation and the difference in attenuation was also striking. Three from those frequencies, which were dominant and had the greatest energy became significantly less as it can be seen on **Figure 7**. Not only noise level

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is lower but the attenuation of the noise in respect of time is shorter in case of the insulated rail.

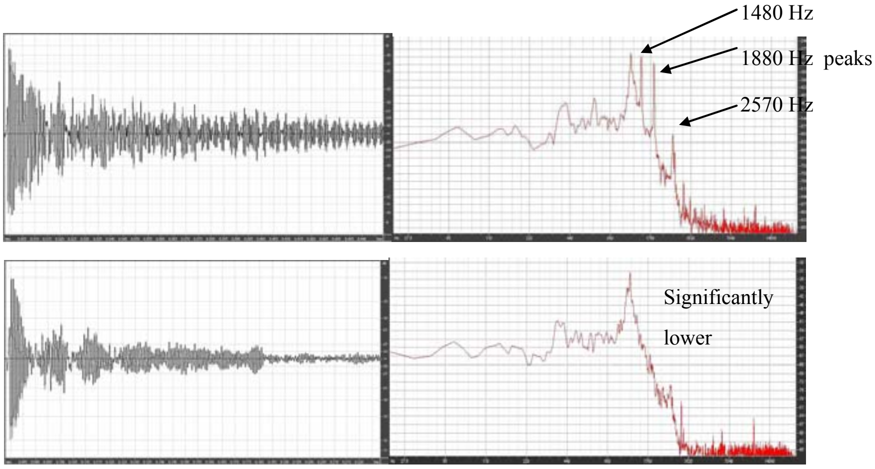

Figure 7. Oscillogram and frequency spectrum of rail without (up) and with web damper (down) developed in Hungary

3.5. Noise and vibration reduction on bridges

Tracks on bridges or in tunnels are sensitive sections. Steel bridges are particularly noisy, they exhibit low internal damping and as the train rolling over it excites the rail and through the fasteners it is transmitted to the gilders and to the whole bridge structure. Vibration and structure-borne noise can be reduced by the installation of resilient fastenings (**Fig. 8. left)**, with the elastic spring supporting of girders (**Fig. 8/middle**) or according to a brand new technique the body of the bridge is insulated with absorbers (**Fig. 8/right**).

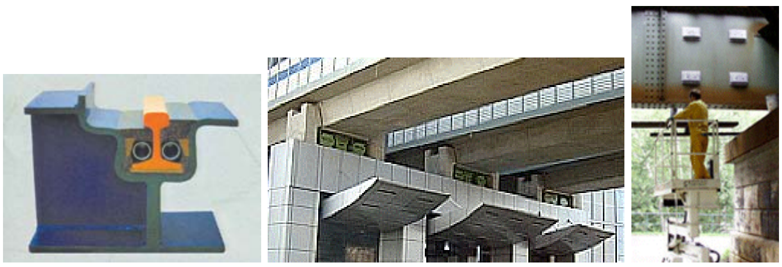

Figure 8.: Noise and vibration insulation on bridges

The structure introduced on Fig. 8./left is unique, it was specially design for achieving a high degree of noise and vibration isolation on steel bridges. Here the

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channel for the continuously embedded rail is intergrated into the bridge structure. Generally it was measured that a passing train at 60 km/h generatess the same noise level as on a ballasted track and 2 dB reduction was measured at 80 km/h.

Bridge absorber (Fig. 8./right) were installed and the effect was examined on a steel bridge in Vienna. The railway track with wooden sleepers was fixed down directly on the steel girders. More than 300 bridge absorbers each with 32 kg weight were placed on the longitudinal web plates and the cross girders. After the measurements it was established that these absorbers resulted 3-5 dB vibration reduction in 20-4000 Hz interval.

4. Conclusions

Noise and vibration generated by transport is very complex that is why the mitigation of them is also very complex. To achieve the required result the above-discussed solutions are often needed to be applied together. With the combination of these methods even 40 dB(A) decrease can be expected. But of course the application of them means in most of the cases very high extra costs and some of these investments never cover the costs. However these investments have got significal additional advantages mainly the improved circumstances of life with lower noise and vibration level.

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Influence of the annual variation of the humidity content of the subgrade on the ballast coefficient of the railway tracks

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Summary:

The Budapest University of Technology and Economics, Department of Highway and Railway Engineering carried out measurements of operating railway tracks on the Budapest – Vác – Szob international trunk line of Hungary, between June 2000 and October 2002.

The aim of the measurements was to determine the internal forces induced in the superstructure by moving of locomotives. Four major internal forces were investigated in the tracks: the geometrical conditions of the tracks determined by track-measuring vehicle, displacement of the elements of the superstructure due to moving vehicles, vibrations induced in and around the track by moving vehicles, and clamping force of the fastening clamp.

In this paper, only the results of the vertical displacement of the sleeper in the ballast are discussed.

The annual distribution of the rainfall in that region are illustrated on diagrams and commented. The recorded depth of the top level of the ground water is indicated in diagrams. A few statements are made on how the annual temperature affects the evaporation in that region throughout the year.

Finally, relationships are drawn on how the annual distribution of rainfall, the annual variation of the level of the ground water, and the temperature influenced evaporation has affect on the strain parameters of the railway track's, how the elastic compression of the subgrade changes under the same wheel load, and finally, how the ballast coefficient of railway track changes.

KEYWORDS: ballasted railway tracks, vertical displacement of sleeper, ballast coefficient, annual rainfall.

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1. INTRODUCTION [1], [2]

The Hungarian State Railways (MÁV Rt.) charged the Budapest University of Technology and Economics, Department of Highway and Railway Engineering, to carry out measurements of operating railway tracks on the Budapest – Vác – Szob international trunk line of Hungary, between June 2000 and October 2002. The aim of the measurements was to determine the internal forces induced in the superstructure by moving of locomotives. Four major internal forces were investigated in the tracks:

1. the geometrical conditions of the tracks determined by track-measuring vehicle,
2. displacement of the elements of the superstructure due to moving vehicles,
3. vibrations induced in and around the track by moving vehicles,
4. clamping force of the fastening clamp.

In this paper, a part of the results of the displacements of the rail and the sleepers are discussed.

2. MEASUREMENTS OF DISPLACEMENTS OF THE SUPERSTRUCTURE LEMENETS OF RAILWAY TRACKS [1], [2]

During the railway track measurements, the followings were determined:

- vertical displacement of the inner and outer sides of the rail-base in respect to the sleeper, (relative displacement),
- horizontal lateral displacement oh the railhead in respect of the sleeper (relative displacement),
- vertical displacement of the sleeper measured against the mast supporting the overhead electric wire (absolute displacement).

The vertical displacements were measured on four sleepers in the left-track. Left and right tracks are understood in increasing order of chainage. In this paper, only the results of the left track are presented. The position of the track measurements was not far from the entrance of Dunakeszi station, that is the neighbourhood of Budapest. Figure 1 indicates the tracks and the site where the measurements were carried out. The measurements were carried out twice a year, once every Spring and once every Autumn through 3 years: June 2000, October 2000, April 2001, September 2001, May 2002 and September 2002.

Figure 1: The site of the track measurements

3. TRACK STRUCTURES [1], [2]

The superstructure elements of the track:

- Rail type: UIC 60,
- Sleeper spacing: 0,60 m,
- Type of sleepers: LW,
- Tension clamp for rail fastening: Skl1 manufactured in Hungary.

The rail-fastenings in the left track are equipped with hard plastic railpads made in Hungary. Table 1 summarises the most important technical parameters of the LW types of prestressed reinforced concrete sleepers manufactured in Hungary. The track superstructure is shown on Figure 2.

The railway track is in a 1 to 3 m deep cut.

The site track-measurements were carried out by using Hungarian type locomotive of V43. It has four axles, and a total weight of 800 kN. The locomotive passed

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through each measuring point at four different speeds: at V = 5 km/h, 40 km/h, 100 km/h and 120 km/h, and at each speed at least four times.

Table 1: Most important technical parameters of the LW types of prestressed reinforced concrete sleepers

Unit	LW
Length [mm]	2500
Maximum width [mm]	300
Maximum height [mm]	236
Height under the rail base	214
Area of bottom surface [mm2]	840000
Mass [kg]	299

4. METHOD OF TRACK MEASUREMENTS [1], [2]

We installed the sensors for displacement at the following points:

- on the outer side surface of the rail-head to measure the horizontal displacement of the rail-head,
- on the inner and outer sides of the rail base to measure the vertical displacement of these points in relation to the sleeper,
- on the top surface of the sleeper to determine the absolute vertical displacement of the sleeper in the ballast bed in relation to the mast supporting the overhead wire.

The arrangement of the sensors on the left track are illustrated on Figure 2.

A console was mounted on the mast supporting the electric overhead line. One end of the sensor measuring the vertical displacement of the top surface of the sleeper was fixed to the end of the console, and its other end was set to the sleeper. The outer end of the console was anchored to the ground by tensioning wires in order to eliminate the vibration of the end of the console when the locomotive passes by the measuring points. Figure 1 illustrates the console and its fixation.

5. RESULTS OF THE TRACK MEASUREMENTS [1], [2]

The vertical deflection of the rail measured against the sleeper is negligible due to the very hard plastic railpad. It varies in the range of 0 – 0.09 millimetres. Figure 3 indicates the averaged value of the total vertical displacement of the sleepers in the ballast for locomotive speeds of 5 km/h, 40 km/h and 100 km/h, for the six time periods of measurements from June 2000 to September 2002.

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Figure 2: Superstructure of the left track and the inserted sensors for displacement and vibration

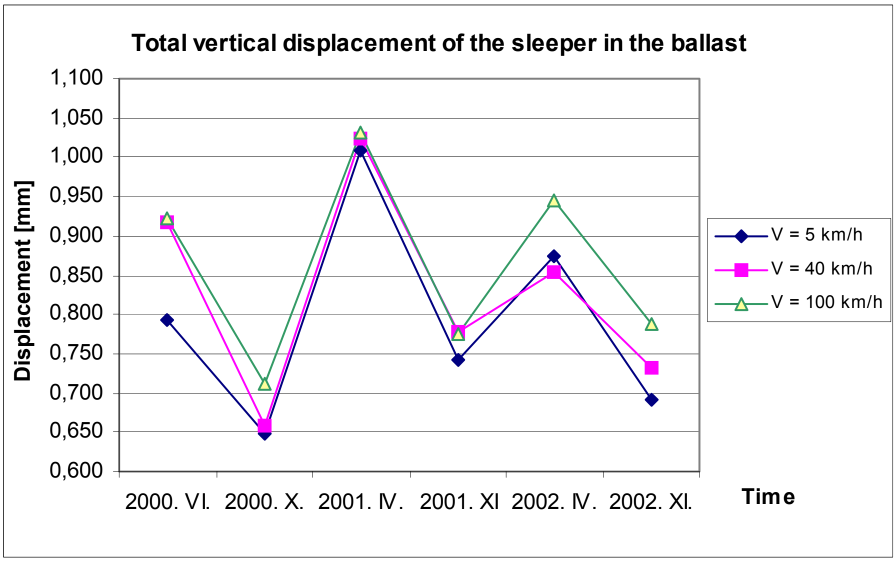

Figure 3: Total vertical displacement of the sleeper for time periods of measurements from June 2000 to September 2002

It is remarkable on Figure 3 that high displacements were obtained in April, May and June and much lower displacements in September and October.

The strain parameters of the subsoil greatly depend on the humidity content of the soil. If the upper part of subgrade is saturated, its strain parameters and deformations are higher than in dry condition.

6. THE BALLAST COEFFICIENT [2]

The elasticity of the railway track can be expressed by several ways. One of them is the ballast coefficient. The ballast coefficient can be calculated from the vertical sinking of the rail by using equation (1):

$$C = \frac{Z}{4 \cdot s \cdot y} \sqrt[3]{\frac{Z}{E \cdot I \cdot y}} \quad \text{[N/mm3]} \tag{1}$$

where: C [N/mm^3] : ballast coefficient,

Z = 100000 N : static wheel load of the applied locomotive type of V43,

y [mm] : the measured vertical displacement due to the load of the locomotive,

s [mm] : width of the substituting longitudinal beam,

E = 210000 MPa : elasticity modulus of UIC 60 type of rail,

I = 30,55·10^6 mm^4 : moment of inertia of UIC 60 type of rail,

The width s [mm] of the substituting longitudinal beam is obtained from equation (2):

$$s = \frac{a \cdot b}{k} \quad \text{[mm]} \tag{2}$$

where: a = 1000 mm : half of the length of the bottom surface of the sleeper of type of LW, on which the sleeper is supported by the ballast,

b	=	300 mm	:	width of the bottom surface of the sleeper of type of LW,
k	=	600 mm	:	the sleeper spacing in the track.

The width s [mm] of the substituting longitudinal beam is obtained to be 500 mm.

The ballast coefficients were calculated for the track according to equation (1) in two cases. In the first case, the values of the total vertical displacement of the sleeper were substituted into the values of 'y'. In the second case, the total vertical displacement of the rail was placed in the values of 'y' of equation (1). The difference between the two results is less than 10 %, therefore the ballast coefficient can be calculated simply from the vertical displacement of the sleeper into the ballast, due to wheel load of the locomotive. Its details are discussed in a previous paper [2].

Figure 4 summarises the change of the ballast coefficients calculated from the vertical displacement of the sleeper in the ballast, through three years for locomotive speeds of V = 5 km/h, V = 40 km/h and 100 km/h.

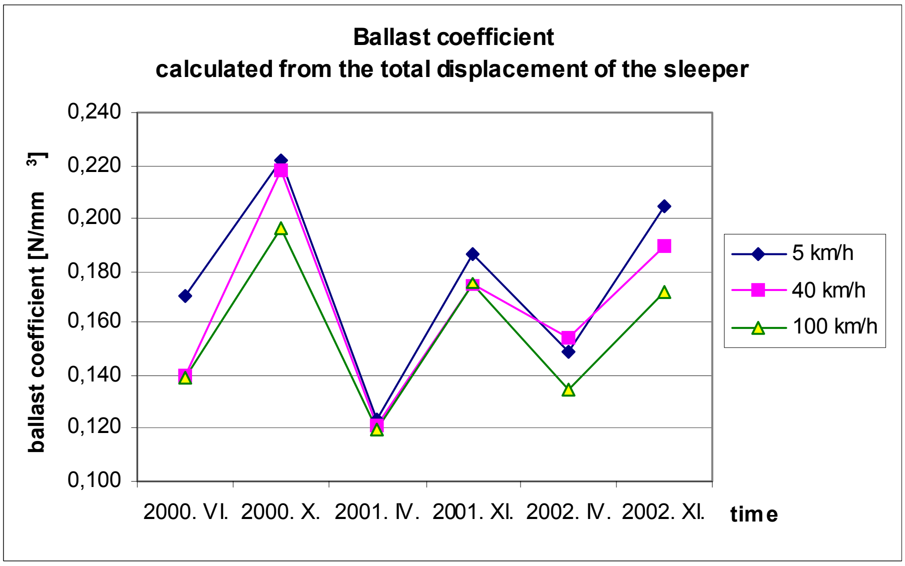

Figure 4: The ballast coefficient calculated from the vertical displacement of the sleeper

It is remarkable on Figure 4 that the ballast coefficient reaches high values in September and October and much lower values in April, and June. It is also due to

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the fact that the strain and deformation properties of the subsoil are influenced by the humidity content of soil.

7. ANNUAL DISTRIBUTION OF RAINFALL, VARIATION OF LEVEL OF GROUND WATER AND EVAPORATION

Figure 5 indicates the annual distribution of the rainfall in that region, measured at the Dunakeszi – Alag meteorology station [3], [4]. The months are shown on the horizontal axis, and the vertical axis indicates the ratio of the rainfall in a particular month to the total annual rainfall. The total annual rainfall is contained in Table 2 for the inspected years.

Table 2: Total annual rainfall measured at the meteorology station of Dunakeszi – Alag [3], [4]

Year	Total annual rainfall [mm]
2000	398
2001	621,3

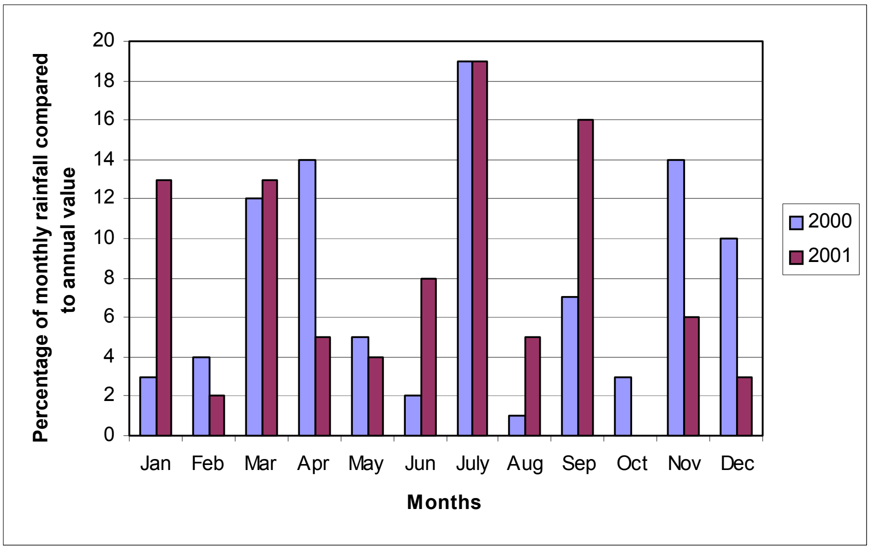

Figure 5: Ratio of the rainfall in a particular month to the total annual rainfall in the years of 2000 – 2001 [3], [4]

It is remarkable on Figure 5 that the amount of rainfall in March through April in the years of 2000 – 2001 was high. The rainfall in August and October in both

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years was low. September 2000 was dry. A rainy period occurred in early September that was followed by a dry sunny warm period.

The surface of the ground water is measured regularly in several wells in the country. The nearest well is at Göd, approximately 10 km's away from where the track measurements took place. The depth of the surface of the ground water measured from the top of the well is contained in Table 3 for the months in which it was measured for the years of 2001 - 2003. No data are available for the months at which the box contains a "–" sign. The minimum and maximum levels of the ground water in this well and the time of its appearance are indicated in Table 4. No data are available for the months at which nothing is illustrated. [5]

Table 3: Depth of surface of the ground water measured from the top of the well of Göd for the months in which it was measured for the years of 2001 and 2002 [5]

Year	Depth of surface of the ground water measured from the top of the well [cm]											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	–	–	452	448	455	469	477	484	484	482	484	484
2002	483	482	481	483	488	492	501	–	–	499	494	–
2003	–	–	–	–	–	–	–	515	520	516	–	–

Tables 3 – 4 and Figure 6 indicate clearly that the level of the top of the ground water is at the deepest level from the top of soil in the months of August, September and October. [5] It shows correlation with that the displacements of the track due to the load of the locomotive are higher in April - May and less in September - October.

Table 4: Minimum and maximum levels of the ground water in the measurement well of Göd and the time of its appearance [5]

Year	Lowest level of ground water		Highest level of ground water	
	Value [cm]	Date	Value [cm]	Date
2001	488	01. 09. 2001.	446	13. 04. 2001.
2002	505	29. 07. 2002.	480	27. 02. 2002.
2003	522	02. 10. 2003.	478	19. 03. 2003.

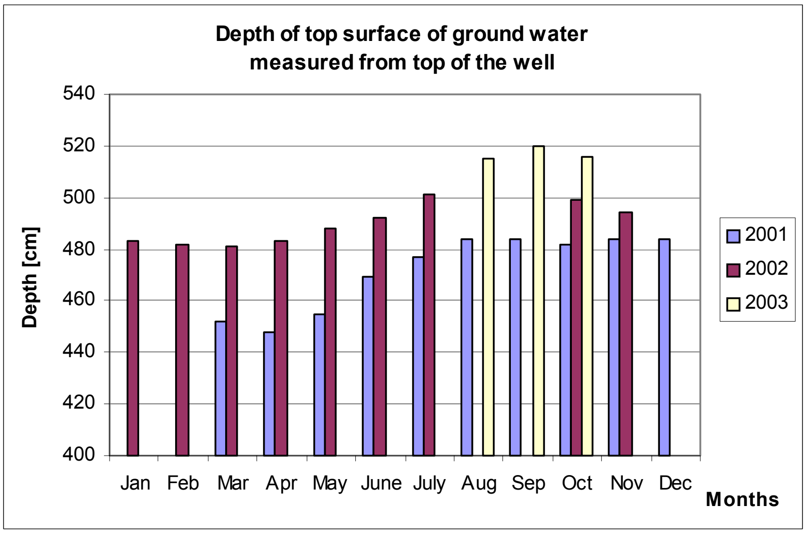

Figure 6: Depth of the top surface of the ground water in the well at Göd, measured from the top of the well [5]

In summer, the highest daily temperature varies around 30° - 35°C in a sunny clear weather, and 18° - 23°C during rainy, cloudy weather in Hungary. The hot temperature in a clear sunny weather accelerates the evaporation of the humidity of the soil and the reduction of the level of the ground water. In winter it freezes usually at night and occasionally in the daytime that slows down the evaporation.

Although Figure 5 indicates high rainfalls in July, it evaporates much faster than a lower amount of rain and snow in winter months or in March or April.

8. CONCLUSIONS

Based on the track measurements of displacements, the calculated ballast coefficients, the annual distribution of rainfall and the variation of the level of the ground water surface, the followings can be concluded:

- The track measurements from 2000 through 2002 indicate that the vertical displacements of the sleeper in the ballast due to the moving wheel load of the locomotive have high values in April, May and June and lower values in September and October (Figure 3).
- The ballast coefficient of the track calculated from the vertical displacements of the sleepers is obtained to have higher values in

September and October, and lower values in April, May and June (Figure 4).

- The amount of rainfall in March through April in the years of 2000 – 2001 was high. The rainfall in August and October in both years was low. September 2000 was dry. A rainy period occurred in early September that was followed by a dry sunny warm period. The track measurements were carried out in late September (Figure 5).
- The surface of the ground water was at a deep level in August through October and high in March through May in the years of interest (Tables 3 – 4 and Figure 6). It shows correlation with that the displacements of the track due to the load of the locomotive are higher in April - May and less in September - October.
- Since the strain parameters and the deformation parameters of the subsoil are influenced by the humidity content, it can be concluded that the annual variation of the weather has a great influence on the ballast coefficient. In springs lower ballast coefficients and higher displacements of the sleeper may be expected due to the moving railway vehicles than in late summers and in early Autumn in Hungary. At this part of the year in Hungary the subgrade is drier therefore higher ballast coefficients and lower vertical displacements will arise due to the same wheel loads as in the spring periods. This effect is noticable especially at sections where the railway track is in a cut.

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Homologation of the polymer-bound BODAN highway-railway crossing pavement elements in Hungary

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Summary

The GMUNDNER FERTIGTEILE Ges.m.b.H. & CO. KG (Austria) charged the Department of Highway and Railway Engineering of the Budapest University of Technology and Economics with the homologation process of the BODAN level crossing elements made of polymer-concrete. Based on the results, the Department has been charged to set homologation reports. The research has been fulfilled whose results are contained in a research report and the final statements are published by B.U.T.E. Department of Highway and Railway Engineering.

The BODAN level crossing system was developed after Hans Ziegler engineer's initiative in Switzerland in the mid 1960s. The prototype was produced by the BODAN Gleiseindeckungs AG. and was built in a railway line by the Lake Boden. The paving elements of the crossing system are still at their original place in the tracks.

After favourable experiences, the elements were mass-produced. The paving elements of the level crossing had an iron frame at that time, and they were produced of cement-bound concrete. Still in the 1970s several countries of Europe used BODAN crossing elements besides Austria and Switzerland (Denmark, United Kingdom, Germany, Spain).

Of the BODAN elements, until the year of 2002, only the cement-bound BODAN highway-railway crossing pavement elements with a steel frame were constructed in railway tracks. The introduction of the polymer-bound BODAN highway-railway crossing pavement elements began in Hungary in the year of 2002.

KEYWORDS: BODAN, highway-railway grade crossings, paving elements, polymer-concrete,

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1. INTRODUCTION

1.1. Foregoings outside Hungary

The BODAN level crossing system was developed after Hans Ziegler engineer's initiative in Switzerland in the mid 1960s. The prototype was produced by the BODAN Gleiseindeckungs AG. and was built in a railway line by the Lake Boden. The paving elements of the crossing system are still at their original place in the tracks.

After favourable experiences, the elements were mass-produced. The paving elements of the level crossing had an iron frame at that time, and they were produced of cement-bound concrete. Still in the 1970s several countries of Europe used BODAN crossing elements besides Austria and Switzerland (Denmark, United Kingdom, Germany, Spain). Since then, the system has been patented in most industrially developed countries of the world. The further development of the system was mainly conducted by the Swiss BODAN Gleiseindeckungs AG., the Semperit AG., the Austrian Gmundner Fertigteile GmbH and the British Dow-Mac Concrete Ltd. – presently called Constain Dow-Mac. The most significant patent is owned by the Gmundner Fertigteile GmbH., but the British Constain Dow-Mac also has an important amount of patent.

From 1985 on, the Gmundner Fertigteile GmbH. produced the BODAN paving elements without iron-frame, of synthetic polimer-bound concrete. Until 1999, eighteen countries applied BODAN crossing elements in level crossings. The relevant quantity and construction data can be found in table 1. According to these data there have been more than 6000 BODAN-type crossings around the world so far.

1.2. Foregoings in Hungary

To modernize the traditional, guide-railed, stone-pavement level crossings the MÁV (Hungarian State Railways) tried Hungarian planned, precast crossing pavings with small and large concrete elements in the late 1960s and early 1970s that were unsuccessful.

To solve the still current technical problems MÁV bought the licence to construct and apply the BODAN type paving elements from the Austrian Gmundner Fertigteile GmbH. It was first produced in Barcs. These paving elements were first applied in Budapest, built in the crossing of Üllői street on the Budapest – Cegléd railway line between Szemeretelep and Vecsés railway stations, and at Óbuda railway station, at the end point. During the past three decades the BODAN crossing system has become the most often used type in the Hungarian Railway network. The crossing systems used by MÁV (Hungarian State Railways) is contained in table 2., grouped according to their type (year 2002). Further construction and maintenance problems occured in connection with the crossing paving elements in the last decades. This makes it crucial to cure the weaknesses. So, it is very timely that the Gmundner Fertigteile GmbH. needs to make a business with the synthetic polimer-bound BODAN elements in Hungary.

Table 1.: The quantity of crossings with BODAN paving system

Country	Built-in BODAN crossing produced by GF	First construction
Austria	> 750	1973
Germany	> 1000	
Italy	10	1983
Switzerland	> 600	1971
Slovenia	1	1997
Hungary	> 3600	MÁV 1980
Japan	> 50	1989
France	Discussions	
Spain	> 50	1978
Belgium	> 10	1985
Holland	New discussions	
Luxembourg	New discussions	
Great-Britain	> 300	1971
Denmark	10	1978
Sweden	5	1984
Australia	> 50	1980
USA	Discussions	1999
Canada	Discussions	1999

Table 2.: Crossing systems according to their type, used in MÁV's network:

Type	Quantity [N^o of level crossings]	Quantity [%]
BODAN	3620	61,3
STRAIL	40	7,5
EDILON	4	0,1
Other	1838	31,1
Together	5902	100

2. TECHNICAL DESCRIPTION OF THE POLYMER-BOUND-CONCRETE PANELS OF LEVEL CROSSINGS

2.1. General characteristics

The polymer-bound BODAN level crossing system is a paving system of level crossings with small elements. The statically determined, so called inner elements functioning as bridge elements join to the railweb. The so called outer elements join also with rubber elements one side onto the railbase, the other side onto the concrete base beam. The elements of the crossing system can be applied in single or multi track railway lines, open line sections, and in rail-sidings as well (figure 1). The new BODAN crossing elements are made of polymer-bound concrete. The polymer bound concrete has far more load capacity and better durability of friction resistance than the cement bound concrete.

Figure 1: Polymer-bound paving elements in a double track railway line

The GMUNDER FERTIGTEILE Ges.m.b.H & Co. KG has developed more basic types of the polymer bound BODAN level crossing paving system. The members of the BODAN family are BODAN, LE BODAN, U-BODAN, Y-BODAN and BODAN 2.

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The members of the system match the systems of railway superstructure (e.g. Y-BODAN paving system), to the features of railway traffic (eg.: U-BODAN paving system), and to the sometimes limited time for construction and maintenance (eg.: LE BODAN paving system).

2.1. Characterisitcs of the polymer-bound concrete

The granulated material is made solid by polymer based adhesive. The material of the polymer concrete BODAN paving system is made of unsaturated polyester and dry classified quartz and granite by heat bond. The mechanical features of the polymer concrete are in table 3., compared with the features of cement based concrete.

Table 3.: Mechanical features of the polymer and cement concrete

Mechanical property	Polymer concrete	Cement concrete
Compressing strength [N/mm^2]	105	30 – 75
Bending strength [N/mm^2]	16	5 – 11
Tensile strength [N/mm^2]	15	3 – 9
Coefficient of thermal expansion [mm/m/°C]	0,18	0,09
Resistance to abrasion [%]	0,5 – 1,0	2,0 – 5,0
Electric resistance [MΩ]	10^6	Depends on humidity
Water absorption qualities [%]	< 0,2	> 1

Polymer concrete is applied mostly in Europe, in the USA and in Japan. Germany is the most frequented country in Europe, most of the equipment for production and construction is made there.

Most important advantages of polymer covering elements:

- Higher strength,
- Narrower structure,
- No problems with electric isolation or electric circuit,
- Produced in various forms,
- No water overflow,
- No frost damage,
- High frictional coefficient on the whole surface of the element,
- No corrosion.

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3. DETAILED DESCRIPTION OF THE POLYMER BOUND BODAN PAVING SYSTEM OF LEVEL CROSSINGS

3.1. The „BODAN " level crossing paving system

The establishment, the geometric and mechanical features of the BODAN paving elements are independent of the rail system, the type of the sleeper and the construction of the rail fastening. The elements of the system can be built in all types of level crossings with a ballast bedded cross-sleepered superstructure. The elements of the BODAN system are the followings:

The inner and outer panels (IP, AP)

Size of the „IP 1435" inner BODAN paving elements:

- width: 600 mm,
- length: 1445 mm (or according to the gauge),
- thickness: 120 mm,

Size of the „AP 750" outer BODAN paving elements:

- width: 1200 mm,
- length: 750 mm,
- thickness: 100/120 mm,

Size of the „AP 1400" outer BODAN paving elements:

- width: 600 mm,
- length: 1200/1470 mm (or according to the distance between centres of lines, or local features),
- thickness: 100/120 mm.

The material of the elements is GEFCON polymer concrete. The upper surface is covered with a rough granulated sliding layer, which increases resistance to slipping and has a high SRT value.

Rubber profile

The paving elements are built on the rails with rubber profiles. These rubber profiles consist of two parts in case of BODAN inner paving elements:

- An upper profile (PIO) and
- A lower profile (PIU).

The rubber profiles of the outer elements consist of a single part (PA).

Closing, supporting beam element (AST-H)

A beam element called GEFCON supports the system, which is as high as the upper surface of the outer element. It proves a perfect connection to the road cover due to its form and material, and clearly divides the BODAN elements from asphalt which is disadvantageous to maintenance.

Base beam (WUB)

The prefabricated base beam helps to prepare the foundation of paving elements. Its size:

- width: 500 mm (or according to the local circumstances),
- height: 300 mm,
- length: 1200 mm, 2400 mm, 3600 mm.

The beams can be laid next to one another to their front on a wet foundation layer. The cross direction draining helps to lead away water from the area of the crossing. According to the local circumstances, it is possible to apply monolithic concrete bodies, its sizes are:

- width: 270 mm,
- height: 450 mm.

The outer elements are founded by the supporting element or on the rail. The vertical movement of the track can be continuously followed while their outer side join to the roadway.

3.2. The „LeBODAN" level crossing cover system

The elements of the LeBODAN system – like in case of the BODAN system – are flexibly supported by the rails, and are independent of the railtype, the type of the sleeper and that of the fastening (figures 2 – 3). The middle elements of the crossing join together by drop brackets, and are supported by a single-unit rubber profile, according to the size of the rail.

3.3. The „U-BODAN" paving system of level crossings

The U-BODAN crossing system has been developed specially for urban railways. The thin cross section of the light elements enables quick manual installation. Due to their little size, the elements can be deponated even inside tunnels beside the tracks. It was developed so that the standard elements of the BODAN system could be used, concerning the different superstructure of the urban railways.

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Figure 2: LeBODAN type of paving element

Figure 3: A highway-railway grade crossing with LeBODAN paving elements on the Linz-Selzthal railway line at Rossleiten

3.4. The „Y-BODAN" Level crossing system

The elements of Y-BODAN level crossing system have been developed for tracks with Y sleepers. The asymmetric setting of the sleepers is compensated by asymmetric crossing elements. The division of fields was according to the BODAN system, so the BODAN rubber profiles can be used.

3.5. The „BODAN 2" paving system of level crossings

The elements of the BODAN 2 crossing system are similar to the elements of BODAN system. The difference is that the supporting edges have been strengthened and put lower, the weight of the elements has been decreased. The form of the rubber profiles has been changed, so that the same tool could be used both with the inner and the outer profiles. The BODAN 2 system has kept all the advantages of the BODAN system.

4. PHYSICAL PROPERTIES OF THE PAVING SYSTEM OF LEVEL CROSSINGS

4.1. Static framework

The BODAN elements are self-supported „plate bridges", that are based on the rubber profiles of the rails by consoles on their inner sides. The elements bridge over the space between the two rails. There are similar bridging elements between rails and the road surface that are based on one side onto the rails, on the other side onto the finishing and supporting base beams. The usage of rubber profiles is needed to decrease the dynamic loading of transportation on the rails and the crossing elements.

The LeBODAN elements are self-supported „plate bridges", that are based on the rubber profiles of the rails by consoles on their inner sides. The elements support each other by their twins in the centre of the track, and the twin elements are based on the other rail by a rubber profile. Due to this solution, the plates can be constructed like the two wings of a door.

4.2. Loading classes

The covering elements are ranked into three classes according to loading:

- Traffic with heavy loading: G I loading class,
- Traffic with middle loading: G II loading class,
- Traffic with low loading: G III loading class.

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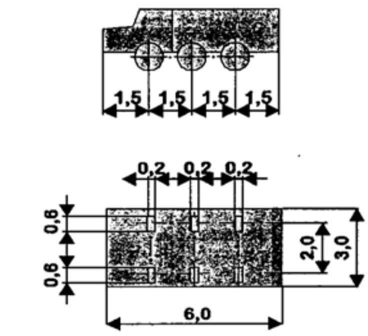
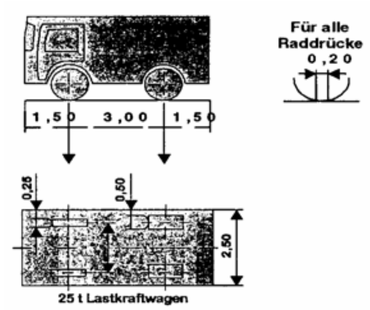
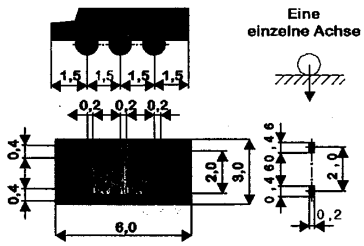
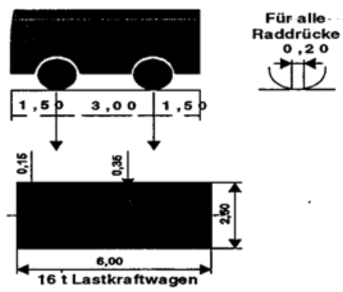
The features of the loading classes can be found in table 4.

Table 4.: Loading classes of BODAN crossing elements

Loading class	Standard	
	DIN 1072 bridge class (German standard)	ÖNORM B 4002 bridge class (Austrian standard)
GI	bridge class: SLW 60/30 full weight: 600 kN wheel-load: 100 kN  b_1 = 60 cm l = 20 cm	bridge class I full weight: 250kN wheel-load: 85 kN  b_1 = 50 cm l = 20 cm
GII	bridge class: SLW 30/30 full weight: 300 kN wheel-load: 50 kN, or the full load on one axle: 130 kN  b_1 = 40 cm b_1= 46 cm l = 20 cm l = 20 cm	bridge class II full weight: 160 kN wheel-load: 55 kN  b_1 = 35 cm l = 20 cm
GIII	Substitutional uniformly distributed load: pmin = 5 kN/m	Substitutional uniformly distributed load: pmin = 5 kN/m

4.3. Surface roughness

The surface roughness of the pavement can be determined with the portable pendulum SRT (skid resistance tester). The tool has been developed by the British Transport and Road Research Laboratory (TRRL) that helps to determine the roughness between the tyres and the wet road surface. The tool has been credited for 50 km/h speed. The lowest needed roughness of the crossing must be 0,55 – 0,75 according to the TRRL Marshall committee. The roughness of the surface of the polymer adhesive BODAN elements can be increased to 0,7 – 0,9 by covering them with a bauxite material.

4.4. Electric isolation

The polymer elements are electrically non-conductive, which is a great advantage against the steel framed concrete elements. (The concrete elements are produced with steel frame that is conductive.)

5. PRODUCTION, CONSTRUCTION AND MAINTENANCE OF THE POLYMER BOUND CONCRETE BODAN PAVING ELEMENTS OF LEVEL CROSSINGS

The basic material of the polymer adhesive concrete is unsaturated polyester by-product, made of quartz and granite by heat bond. The mortar is partly solid in the shuttering 30 minutes after casting. The process makes heat, this is the gel point of the polymer concrete. One and a half hours after the casting it is solid enough and can be moved without shuttering in the area of the producing plant. After day's shift it must be kept in room temperature for a night and the next day it can be transported to the storage place.

The additional materials of the polymer-concrete sorted into silos, the size of he granulates is maximum 6 mm, minimum 75 micron. The smallest granulates are added first into the mortar-mix. The weight of the polyester-rosin adhesive is 10 % of the smallest granulated additional. In the mixer the adhesive and the smallest granulated additional is mixed, and then the catalisator is injected, the weight of which is 1 % of the rosin adhesive. The larger granted additional are then added continuously. After making the polymer concrete mortar, the productions of the concrete elements have the following phases:

1. Preparing the shuttering for the concrete elements,
2. Putting the ironwork of he elements into the shuttering,
3. Pouring and making even the polymer concrete mortar in the shuttering,
4. Putting crushed stones onto the upper surface of the elements to make it rough,

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5. Putting away the shuttering from the elements,
6. Lifting the elements from the shuttering,
7. Transportation and storage of the elements in an outdoor place.

6. CERTIFICATE OF USAGE OF THE BODAN HIGHWAY-RAILWAY CROSSING PAVEMENT ELEMENTS IN HUNGARY

Based on results of the testing, the certificates issued outside Hungary, and the general rules for constructions, the Budapest University of Technology and Economics, Department of Highway and Railway Engineering has qualified, the polymer-bound BODAN highway-railway crossing pavement elements to be satisfactory in respect of the usage and constructions in Hungary. The polymer-bound BODAN pavement elements can be constructed in railway tracks of the Hungarian State Railways AG., the Győr – Sopron – Ebenfurth Railway AG. urban railways and street railways, by keeping the regulations of construction and operations set forth in the Certificate handed out by the Department of Highway and Railway Engineering.

References:

1. Homologation report of the polymer-bound-concrete railway level crossing paving elements produced by Gmundner Fertigteile GmbH, Budapest, 2002
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Railways

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Railway track – fast and nonpolluting transportation system

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Summary

This paper presents the advantages of railway transportation weigh against road and air transportation insisting on environment protection and travel times, the benefits of high-speed circulation on classic track and the achievements made in Western Europe on non-conventional track.

KEYWORDS: railway, environment protection, high-speed trains, safety.

1. INTRODUCTION

The railway's revival on the end of the XX-th century was dictated by the necessity of a very fast and safe transportation system (by modernizing the railway invented on the XIX-th century) and in the same time by the excessive pollution due to road network developing and the increase of the vehicle's number.

The atmosphere's pollution can be no longer tolerated. We can reach a limit when life existence itself will be endangered. This is why more and more scientists from various field of interest are signalizing this extreme acute problem for humanity's future.

Although on the 1992 U.N.O.'s Convention regarding the climatic changes and on the 1997 Kyoto Protocol a global strategy for gas emission reduction was adopted, the percent of toxic gas release continues to rise dangerously. According to the statistics, the transportation sector is responsible for 27% of CO emission in the OCDE countries, 25% in the EU, 30% in the USA, 22% in Japan, 17% in Africa and 34% in the Latin America.

In accordance with a recent report carried out by the Ecofys and Franchofer Institute, none of the European countries that subscribed to the protocol has kept its commitment regarding CO gas reduction.

This report recommends especially actions towards the transportation system, which represents the key sector in the pollution reduction policy. One of the most efficient solutions for substantial gas emission reduction in this sector is to attract a higher percentage from the road transport (both passengers and wares) towards the railway track.

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As follows, we present a comparison between different systems of transportation (road, rail and airplane) on the subject of environment protection, speeds and transport safety.

The III-rd millennium cannot be conceived without very modern transportation systems. The safest, fast and less polluting transport system is the railway; therefore, the development of the railway becomes a very important issue for every country not only for a high speed and secure system, but also for environment protection.

2. ENVIRONMENT PROTECTION

The Earth can no longer be polluted endlessly by transportation systems. This pollution can be diminished only by a modern railway track expansion.

As follows, we present the air pollution due to different means of transportation.

The quantity of polluting residues is given for 1 passenger x km.

- airplane (civil aviation) 356 g. polluting residues
- auto vehicles 12 g. polluting residues
- trains 0.6 g. polluting residues

We do not have information regarding the military aviation pollution.

- CO_2 train : auto vehicle 1:29
- SO_2 train : auto vehicle 1:11

The carbon monoxide, azoth dioxide and led emission are practically negligible in the rail sector.

In Table 1, we present some information regarding polluting residues resulted from the carburant use at 100 passengers x km, measurements made by the German Administration (DBAG) in 1996:

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Table 1 – Toxic residues eliminated in the atmosphere

TOXIC RESIDUES	AUTO VEHICLE	AIRPLANE	ICE TRAIN
CO_2 (kg/100 passenger × km)	14.10	17.10	4.2
CO(kg/100 passenger × km)	552	53	1
HC (g/100 passenger × km)	81	14	0
NO_x(g/100 passenger × km)	121	72	5
SO_2(g/100 passenger × km)	7	8	6

In Figure 1 is presented a diagram concerning the toxic emission of different means of transportation and the use of primary combustible:

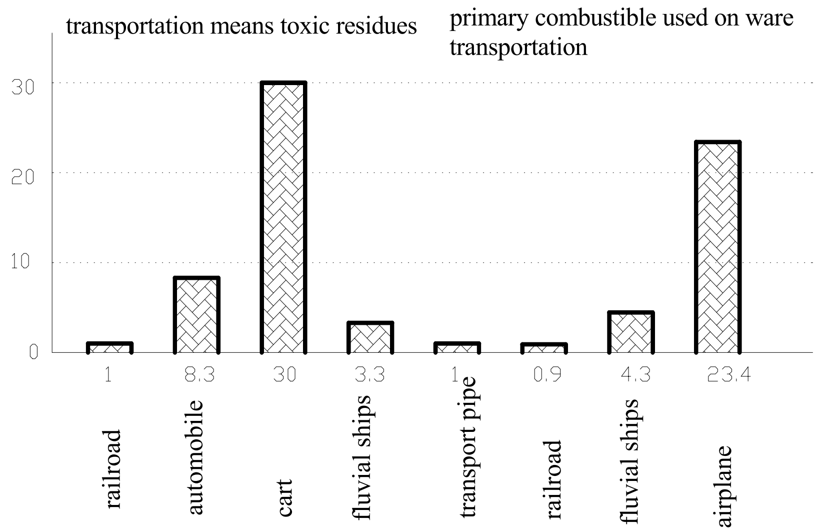

Figure 1 Toxic emission of different means of transportation and the use of primary combustible

Due to the fact that toxic emissions of different means of transportation depend on combustible use, in Figure 2 is presented the specific energy consume depending on speed for 1 passenger x km for auto vehicles, A 320 Plain and high speed train ICE:

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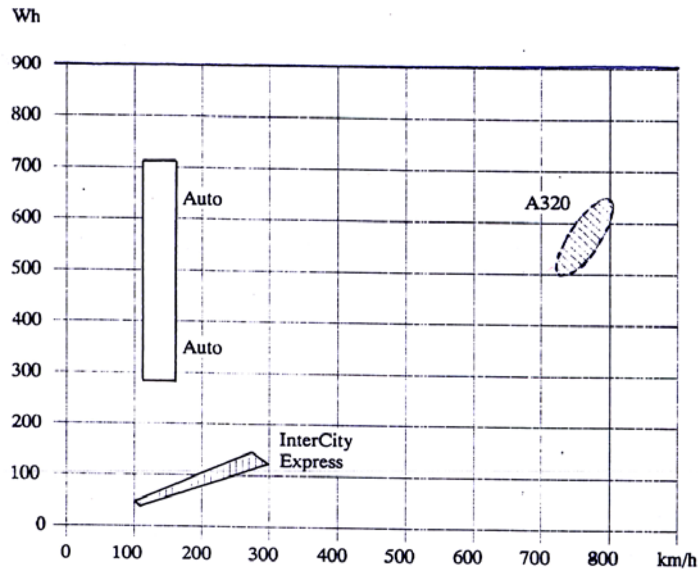

Figure 2 Toxic residues and primary combustible use

Another problem is the phonic pollution – very important when the transport systems cross over great urban agglomerations. In Figure 3 is presented a diagram concerning the phonic pollution by the German measurements:

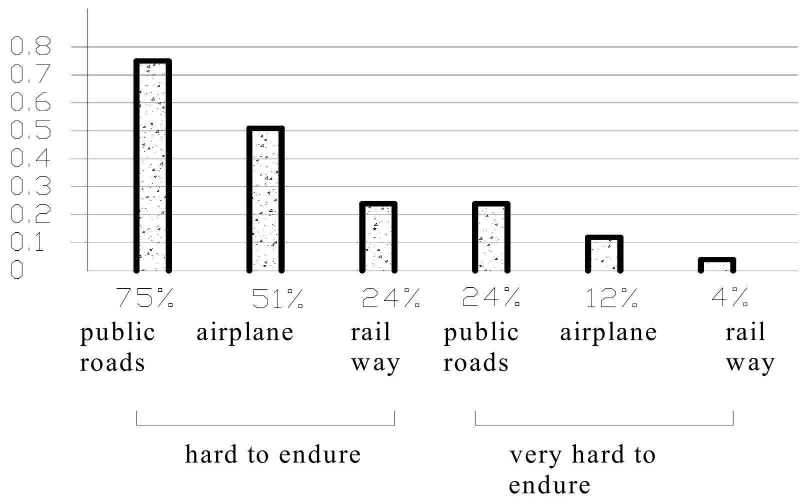

Figure 3 Phonic pollution

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3. TRAINS AS PHONIC POLLUTION SOURCE

The noise made by diesel locomotive on joint track and joint less track is given in Table 2:

Table 2 – Diesel and electric locomotive noise

LOCOMOTIVE	SPEED (KM/H)	NOISE LEVEL DB(A)	
		Joint less track	Joint track
Diesel	30-50	67	70
Electric	30-90	66	72

It is necessary to know the admission noise level on urban areas in order to establish the routes of railway track as shown in Table 3:

Table 3 – Admisible noise level in different areas

AREA'S FUNCTION	NOISE LEVEL			
	Secondary lines		Main lines	
	Day 6-22	Night 22-6	Day 6-22	Night 22-6
Resort areas Balnear areas, hospitals	55	45	60*	50*
Lodgings areas	60	50	65*	55*
Urban lodgings areas	65	55	65*	55*
Industrial areas with lodgings and institutions	65*	55*	65*	55*

*In exceptional cases it can be accepted an increase with 5- 10 dB(A)

4. HIGH SPEED TRAINS

In this section, we present the decrease of travel time using high-speed trains. Those trains run on elastic lines – the sleeper-rail frame is included in a ballast bed.

The reasons why trains are preferred in spite of other means of transportation from the passenger's point of view are safety, comfort and travel time reducing (the approaching town tendency).

To argument that, we present some real facts offered by different railway administrations in Table 4 and in Figure 4 travel time reducing once the high-speed trains were introduced in Germany

Table 4 Travel time reducing using ICE trains

Route	Dist.[km]	Travel times [h]		
		1985	1990	2000
Dortmund-München	750	7.14	5.30	4.00
Köln-München	630	6.03	5.30	3.35
Köln-Frankfurt/M.	220	2.18	2.18	1.00
Köln-Stuttgart	400	3.48	3.10	2.10
Hamburg-München	820	7.03	5.30	4.45
Hamburg-Basel	875	7.34	6.00	6.00
Hannover-München	640	5.40	4.15	3.30
Hannover-Frankfurt	300	3.12	2.15	2.05
Hannover-Basel	700	6.16	4.45	4.30
Frankfurt/M.-München	420	3.44	3.30	2.45

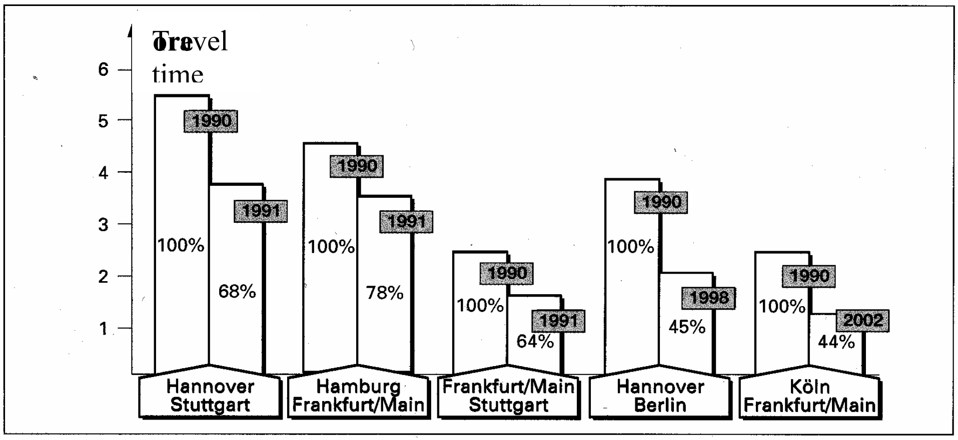

Figure 4 Travel time reducing once the high-speed trains were introduced in Germany

In Figure 5 is presented a diagram regarding travel time reducing using high speed trains (TGV) from Paris to other important centers of Europe:

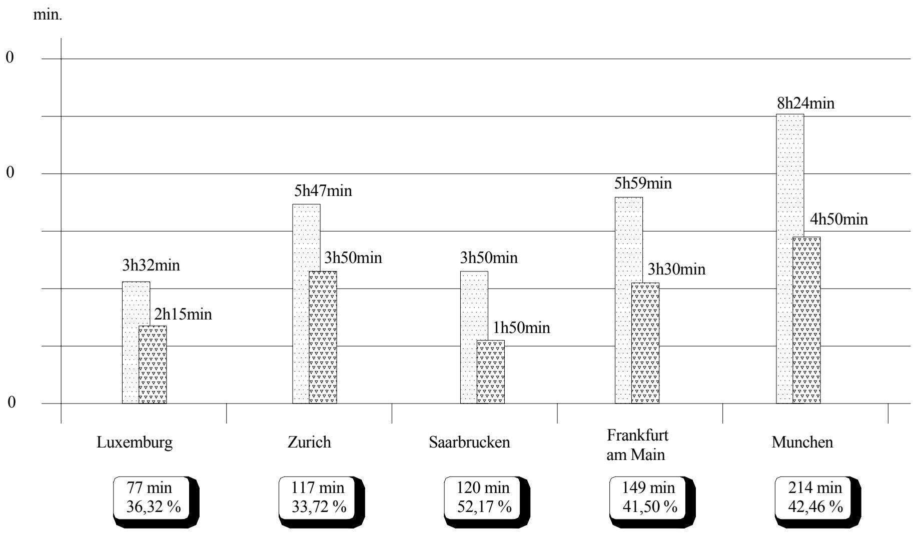

Figure 5 Time economy realized by TGV trains from Paris to mentioned cities

In Table 5 is shown the travel speed and train type in one day, in France (1998/1999):

Table 5 Pairs of trains per day and travel speed (France, 1998/1999)

ROUTE	STATIONS	DISTANCE	PAIRS OF TRAINS, TYPE	TRAVEL SPEED [KM/H]
TGV South-East	Paris - Lyon Paris - Marseille	512 800	25 TGV 16 TGV	249 195
TGV Atlantique	Paris – Tours Paris – Bordeaux Paris – Hendaye Paris – Calais	235 581 816 296	19 TGV 29 TGV 16 TGV 5 TGV, 4 ES	255 195 156 214
International routes				
TGV North Europe	Paris – Londra Paris – Bruxelles Paris – Bruxelles – Köln Paris - Amsterdam	494 312 545 554	26 ES 16 Thalys 16 Thalys 20 Thalys	170 160 135 115

In Table 6 are shown travel times on several important routes from West Europe.

Table 6 Travel times for several routes

ROUTE	TRAVEL TIMES
London - Bruxelles	2 h 40 min.
London - Paris	3 h
London - Köln	4 h 10 min.
Paris - Lille	1 h 20 min.
Paris - Bruxelles	1 h 20 min.
Paris - Amsterdam	2 h 48 min.
Paris - Köln	2 h 55 min.
Bruxelles - Köln	1 h 40 min.
Amsterdam - Köln	3 h 5 min.
Torino - Lyon	1 h 20 min.
Milano - Lyon	2 h 40 min.

Obs: In 1994-1996, shorter travel times were realized than in the Table above on the London – Bruxelles, Paris-Lille, London-Paris and Paris-Bruxelles routes.

A remarkable achievement: France-crossing from north to south (1067 km) using TGV in only 3 hours and 29 minutes as shown in Figure 6:

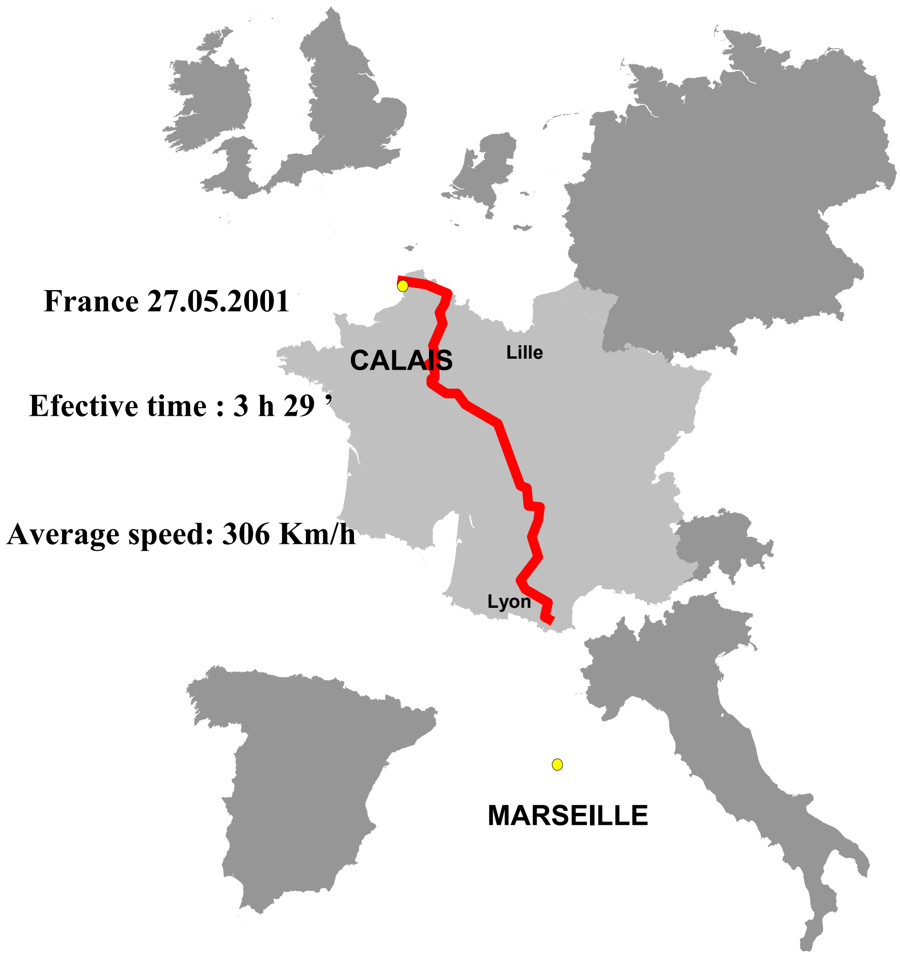

Figure 6 TGV line from Calais to Marseille

Using the TGV in the Mediterranean region, travel times have became shorter as shown in Table 7 :

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Table 7 Travel times in Italy

ROUTE	LENGHT [Km]	TRAIN TYPE	TRAVEL SPEED [Km/h]
Roma – Firenze	316	ES × Eurostar Italy	198
Roma – Bologna	413	ES × Eurostar Italy	156
Roma – Napoli	214	ES × Eurostar Italy	122
Roma – Pisa	336	ES × Eurostar Italy	116
Domodossola - Milano	125	CIS Cisalpio	106

In Table 8 we present a comparative study regarding travel times from London to other european cityes:

Table 8 A comparative study on travel times from London to other European cities using the train or the plain from 1988 to 2000:

City	Railway 1988	Railway 1995	Railway 2000	Flight time 1991	+ Time from airport to destination (h)	= Total flight time (h)
Paris	7,20	3,00	2,35	1,05	+2,00	= 3,05
Bruxelles	7,00	3,00	2,15	1,05	+1,30	= 2,35
Amsterdam	11,00	5,55	3,55	1,05	+1,30	= 2,35
Lyon	10,00	5,00	4,35	1,30	+2,00	= 3,30
Köln	9,15	5,20	3,20	1,15	+1,30	= 2, 45
Frankfurt	11,30	6,50	4,50	1,30	+2,70	= 3,00
Marseille	12,00	7,00	6,35	1,50	+1,85	= 3,35

After September the 11, 2001 waiting times in aerostations are bigger than the ones shown in the Table above.

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Railway track – fast and nonpolluting transportation system

A demand for railway administrations that have in exploitation high speed lines can be formulated: for distances up to 1000-1200 km in actual conditions, during one day's work (aprox. 12 hours), one can travel one-way and return with an approximate 4 hours stationing. So, one third of a day's work should be dedicated to normal activities and two thirds to the travel. This performance can be improved because the medium speed can be still increased. On classic rails, speeds can be increased to the incredible value of 500 km/h. From this speed forward, the experts are orientating themselves to non-conventional systems (electromagnetic sustentation).

In Romania's case, at a speed of 300 km/h, cities like Satu Mare – Mangalia or Iaşi - Timişoara can become ''closer'' in maximum 3 hours.

Train types with distinctive performances that are used in Western Europe since 1998:

- EC EuroCity: international high speed train; connecting different European cities, providing unitary conditions regarding comfort and services;
- IC InterCity: Expres train, connects different important cities of different countries;
- EN EuroNight: night high speed train, providing special unitary conditions for comfort and services;
- EUROSTAR: high speed train used by the French, English and Belgian administrations connecting England and Continental Europe providing special conditions regarding comfort and services;
- ICE InterCityExpress: German's administration high speed train providing special conditions of comfort and safety;
- TGV Train a Grande Vitesse: French's administration high speed train providing travelers special conditions regarding comfort and safety (French administration SNCF holds the record on ''classic lines'' of 515.3 km/h);
- Thalys: high-speed train used by Occidental European countries, providing finer services of comfort and safety.

5. MAGNETIC SUSTENTATION TRAINS

At classic railway track (the interaction between vehicle and rail is realized by the wheel and rail), the maximum speed at which the circulation can be accepted in completed safety and comfort is 500 km/h. In Europe, there are lines where the average speed is over 300 km/h.

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In the developed countries (Germany, Japan) experts are working to put in work non-conventional systems of transportation: realized with induction motors on electromagnetic sustentation. This will be the transport system of the III-rd century.

The principle of air, magnetic or electromagnetic field is shown in Figures 6 and 7:

Figure 6

a) Pressure air jet b) Opened air jet chamber c) Closed air jet chamber with air evacuation at chamber circumference

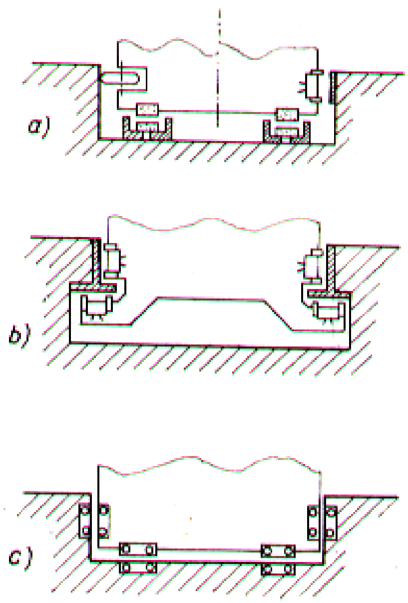

Figure 7

a) Permanent magnetic sustentation
b) Electromagnetic sustentation
c) Electrodynamic sustentation

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A guided transportation system where the friction between vehicle and rail does not exist was a challenge to the engineers since the mid XX-th century. Since 1960, in Japan, research had been started concerning a guided vehicle based on electromagnetic suspension, although the idea itself had been launched in Germany in 1930. For the XXI-th century, German engineers are designing an electromagnetic sustentation line between Berlin and Hamburg, its length: 292 km. On this line, TRANSRAPID trains (Figure 8) will be running on an experimental section of 31.5 km.

Figure 8 TRANSRAPID train

Figure 8 presents the design track and vehicle guiding system:

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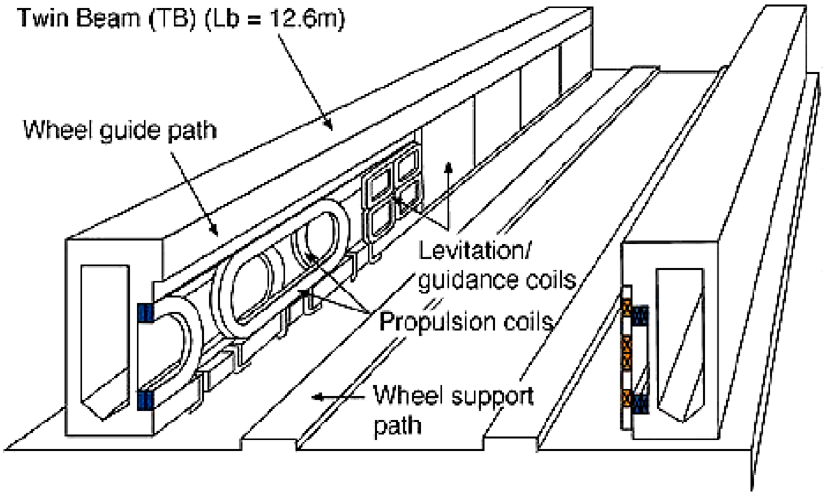

Figure 8 / a, b. Design track and vehicule guiding sistem

Principe scheme regarding linear motors designed in Japan – Figure 9:

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Railway track – fast and nonpolluting transportation system

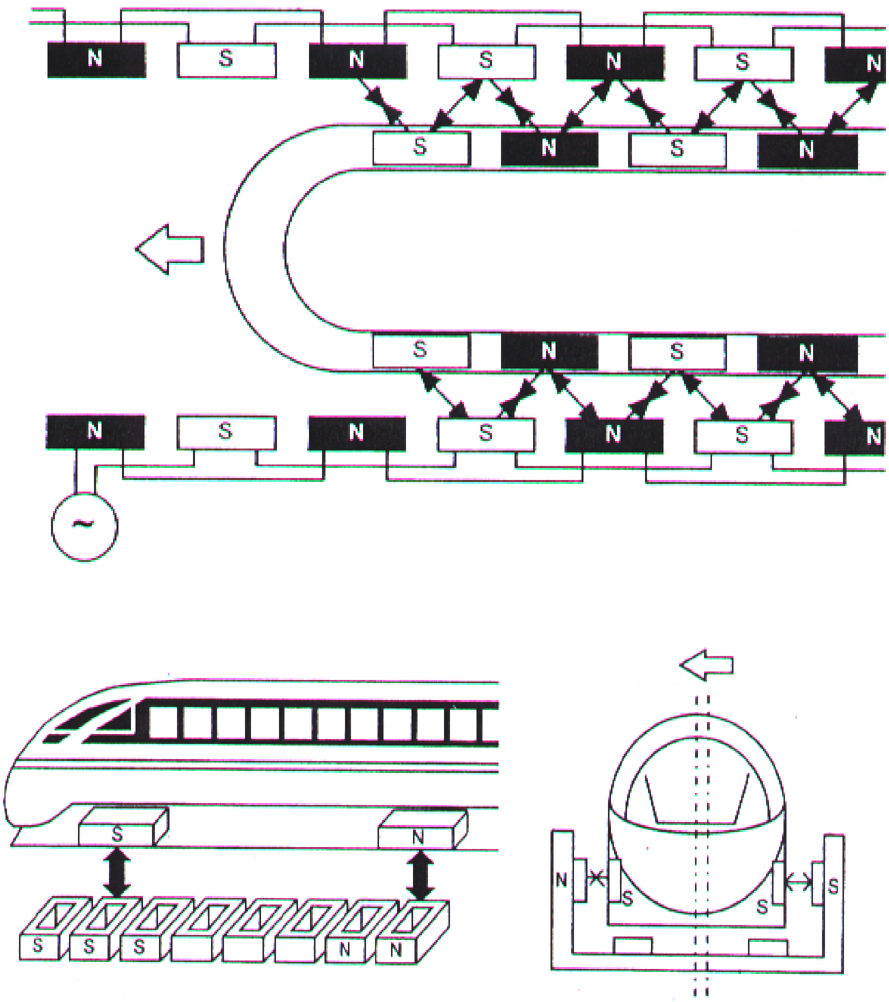

Figure 10 Principe scheme regarding linear motors designed in Japan

International Congresses have been pointed out the great advantages of railway transport.

6. CONCLUSION

As a conclusion and a revision at the same time of the dates shown above, at the International Seminar with the theme of ‘’Transportation policy on the perspective of a united Europe’’ held in France in 1992 at Marly de Roy, comparing the two

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transportation systems brings out the objective necessity to promote the railway system.

- the specific consumption of energy on the railway system is 3.5 times smaller for passenger transportation and 8.7 times smaller for freight transportation;
- toxic residues emission is 8.3 times bigger for passenger transportation and 3 times smaller for freight transportation;
- transport safety is 24 times bigger for passenger transportation compared to auto vehicles and 2.5 times bigger for freight transportation compared to buses.
- the used area for the double railway is equal to a third of the necessary area for a highway with 2 lanes per one direction, having a comparable traffic capacity;
- the sound impact provoked by the road transportation affects a 6.5 times bigger number of urban areas.

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Railways

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Design program for the stability of the jointless railway track

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Abstract

The study of the jointless railway track behavior on high temperatures becomes a necessity because in the rail can appear tensions and phenomenon with spontaneous character and damaging results on the safety of the circulation.

The track works under a variety of efforts, the complexity of elements that compose the frame track, the imperfections and the non-homogenous ballast bed make difficult the correct determination both experimental and statistical of the required parameters under different methods of calculus.

The resistance of the track at transversal displacement is given by the reaction provided by the ballast bed. In case of a well maintained track, this reaction is big enough to take, without displacements, the transversal efforts the rail is normally subjected to.

The rail stability in the horizontal plane must be studied especially in curves where the tendency of buckling towards the exterior of the curve is supported by the geometry of the track itself. A compressed track will never be perfect; there will always be small eccentricities and settlement defects accentuated in time due to the action of the train movement.

1. INTRODUCTION

The rail stability in the horizontal plane must be studied especially in curves where the tendency of buckling towards the exterior of the curve is supported by the geometry of the track itself. A compressed track will never be perfect; there will always be small eccentricities and settlement defects accentuated in time due to the action of the train movement.

2. CALCULUS PARAMETERS

The compression effort from the rail due to high temperatures can reach an appreciable value when the instability becomes a problem.

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G. Köllő, M. Munteanu

Considering the fixing temperatures interval (17°÷27°C – in Romania) and the maximum temperatures that can occur in the rail (60°C), in the central area of the jointless track can appear considerable efforts:

$$P_{\max t} = \alpha \cdot E \cdot A(60° - 17°) = 1038.45 \cdot A \quad (1)$$

$$A = 2A_s \qquad P_{\max t} = 2076.90 A_s \quad (2)$$

Heavier the rail is, higher the compression effort gets. At high effort and in certain conditions the track instability is manifested by buckling in the lowest resistance plan (in the case of modern superstructures (heavy superstructures) - the horizontal one).

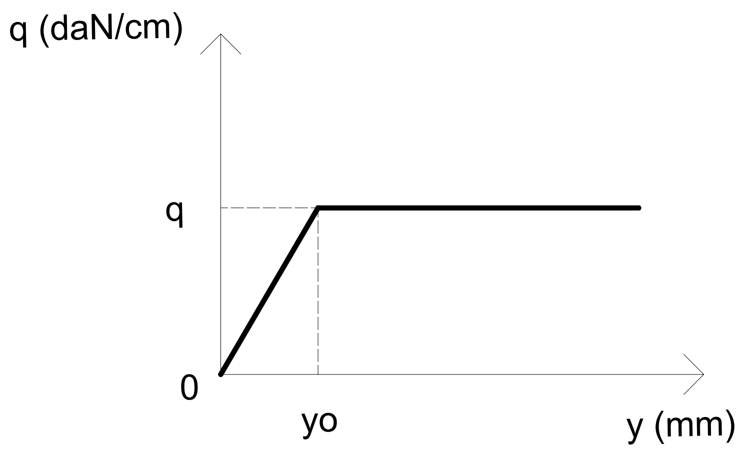

Fig.1 Lateral resistance when the displacement varies

The jointless railway is considered a horizontal frame, laid on the ballast bed, without being fixed and having a special geometry (alignments and spatial curves).

It is necessary to determine the calculus elements of the jointless track in order to prevent instability and to maintain the traffic safety.

The phenomenon of buckling is prevented by both the rails and the frame rail-sleeper rigidity and by the resistance of the ballast bed on the longitudinal and transversal displacement of the track.

The influence of the ballast bed has been determined with the relation:

$$q = qo + C \times y \quad \text{if } y \leq y_o \text{ and } q_p = q \quad \text{(shown in the diagram)}$$

The critical force in case of instability has been calculated using the energetic method.

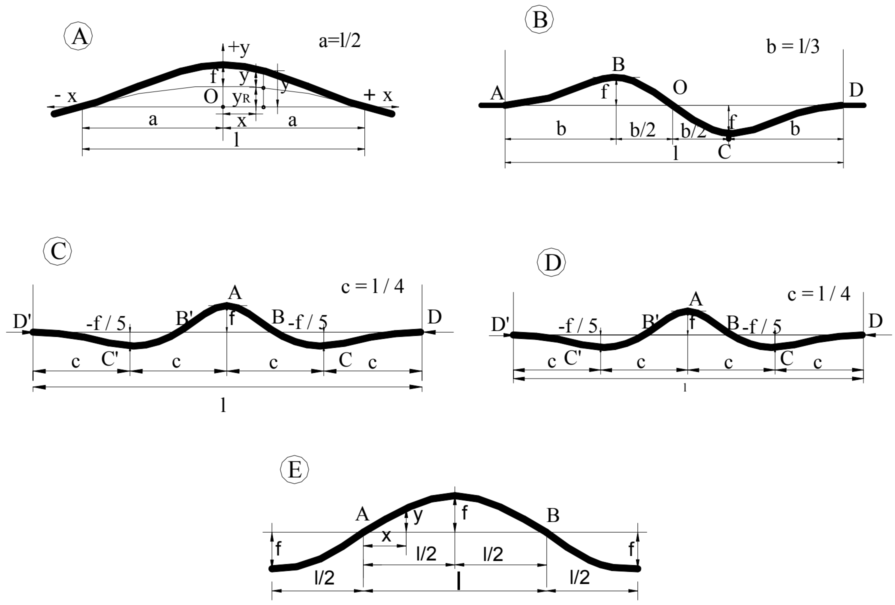

Fig. 2 Geometrical imperfections

For the general case (in curves), the critical force in case of instability is:

$$P_{cr} = \frac{K_1 \dfrac{EI}{l^2} + K_2 q_0 \dfrac{l^2}{f} + K_3 C l^2 + K_4 \dfrac{IM_r}{a \cdot f}}{1 + K_5 \dfrac{l^2}{fR}} \tag{3}$$

For R→∞ (alignment):

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$$P_{cr} = K_1 \frac{EI}{l^2} + K_2 q_0 \frac{l^2}{f} + K_3 C l^2 + K_4 \frac{l M_r}{a \cdot f} \tag{4}$$

Where:

K1-K5 - constants for different types of imperfections;

l - length of the geometric imperfection;

f - deflection of the geometric imperfection;

C - proportionality coefficient for the ballast bed;

E - steel elasticity module;

α - steel linear thermic dilatation coefficient;

A - cross section area for the two rails; $A=2A_s$;

q - resistance of ballast bed on transversal movement of the track;

m - distributed moment; $m = \frac{2 \cdot M_r}{a}$

a - distance from the sleepers axe ;

r - coefficient that characterizes the fastening of the rail on the sleeper;

The equations (3) and (4) are given for five probable forms of geometric imperfections in the horizontal plane:

P_{cr} depends on the mentioned constants and on two independent variables l and f.

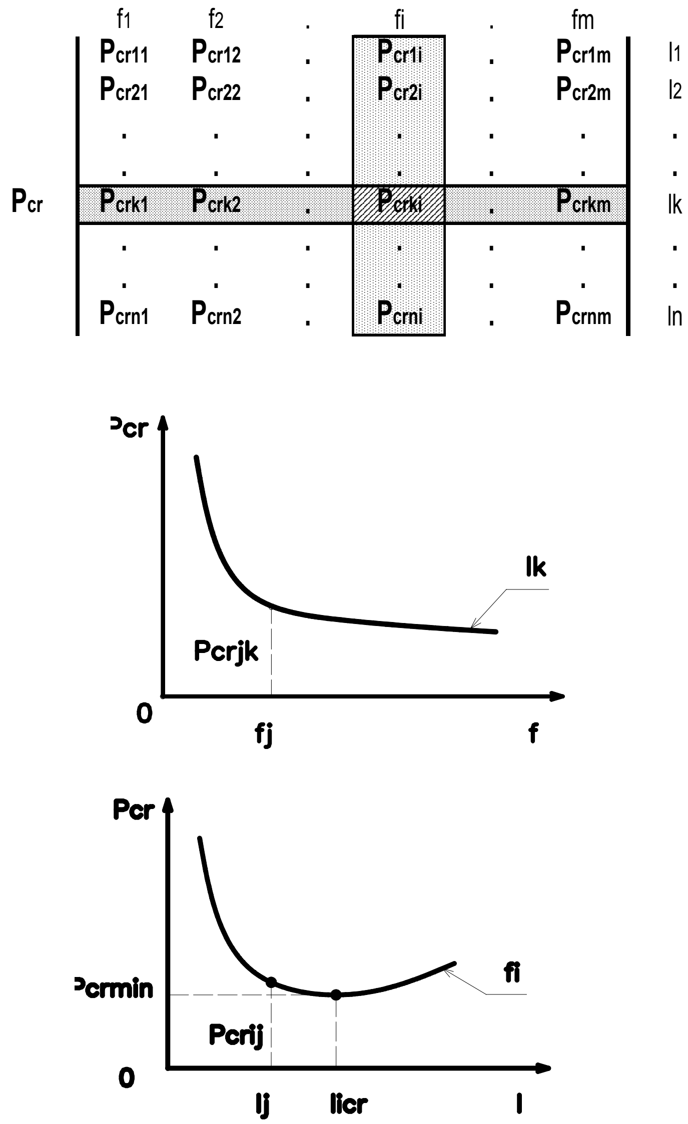

Fig. 3 The critical force matrix

where:

$f = \{f_1, f_2, \ldots f_m\}$ deflections of geometric imperfections

$l = \{l_1, l_2, \ldots l_n\}$ lengths of geometric imperfections

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Example:

For the types of geometric imperfection B in alignment and A in curve the results are:

Table nr. 1

Imperfection type "B", rail type 65, r=300000 daNcm, q=6.0daN/cm, C=2.6daN/cm², qo=3.0daN/cm, a=65cm

f(cm)	0.25	0.50	0.75	1	1.5	2	2.5	3
Lcr(cm)	910.494	1043.00	1117.32	1166.58	1229.04	1267.52	1293.78	1312.89
Pcrmin (daN)	540786	414299	362205	333030	300951	283509	272489	264879

Table nr.2

Imperfection type "A", rail type 65, r=300000 daNcm, q=6.0daN/cm, C=2.6daN/cm², qo=3.0daN/cm, R=450m, a=65cm

f(cm)	0.25	0.50	0.75	1	1.5	2	2.5	3
Lcr(cm)	875.51	903.04	927.20	948.87	986.76	1019.42	1048.33	1074.38
Pcrmin (daN)	251070	236550	224854	215119	199612	187610	177909	169827

The volume of the stability calculus is high due to the variable parameters l; f and the different values of q; r and it can be reduced using a computer aided design program – presented in this paper. The program determines the necessary elements needed to analyze the jointless rail stability.

The necessary condition for keeping the rail stability even at high temperatures is:

$$P_{\max t} \leq c \cdot P_{cr\min} \tag{5}$$

c – safety coefficient, c=(1.3-1.5)

The safety coefficient and the rest of the elements are determined once the temperature starts to change. The rail temperature variation depends on the outside temperature variation. The user can set the temperature variation step, the safety coefficient is calculated and displayed with every variation. It is also displayed the case we are in: stability/instability. The initial data are the superstructure characteristics: (EI, R, q, a, Ki).

The conclusion drawn from the results provided by the program: heavier the rail is (the cross section area is bigger), the safety coefficient decreases which means that at heavy rails the critical force does not increases sufficient to compensate the increasing compression effort from the temperature.

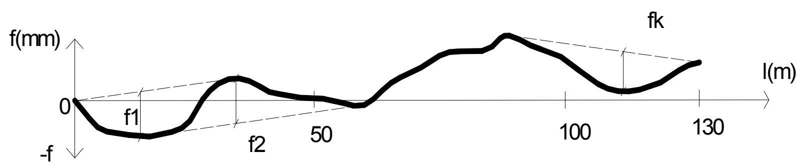
Example:

Geometrical imperfection type B

rail type 60	rail type 65
$P\max t_{60} < P\max t_{65}$	
$Pcr\min_{60} > Pcr\min_{65}$	
Pcrmin = 319391 daN	Pcr min = 333030daN
Pmaxt = 157532.9 daN	Pmaxt = 171552 daN
c = 1.31	c = 1.26

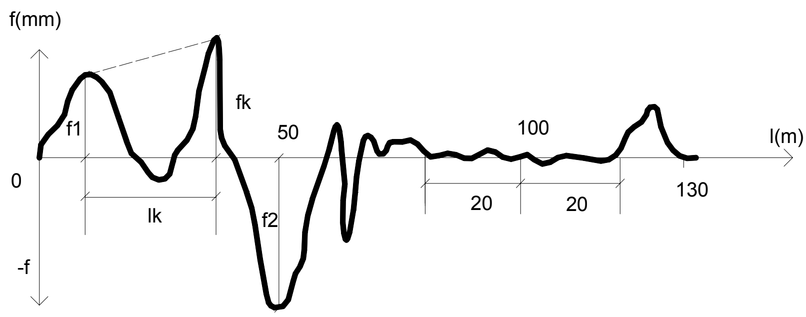
Displacement measurements of the rail in alignments:

- imperfection type: B;
- f1 = 7cm
- Pcrmin = 229600daN
- c = 1.457



Displacement measurements of the rail in curves:

- imperfection type: C;
- f5 = 8 cm;
- Pcrmin = 337700 daN;
- c = 1.457.



3. CONCLUSIONS

The critical force and all the necessary calculus ellements of the jointless rail in traffic are important in order to know the exact state of the rail and to ensure the safety in case of instability.

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