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POSSIBILITY OF APPLICATION OF CONCRETE SLEEPER WITH UNDER SLEEPERS PADS

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Abstract

One of the most sensitive segments of the railway infrastructure are certainly bridges. All steel grid bridges have wooden sleeper attached to the bridge structure and cannot change the height when maintaining the upper structure rails. It has become a practice to reconstruct or replace damaged bridges in the past by taking care that the track construction is separated from the bridge constructions. One way is that steel grid structures are replaced with reinforced concrete structures in the form of a trough or if the spans are larger with steel structures in the form of a trough. The standard classical track construction today is a gangway with concrete sleepers and a ballast of crushed stone material. Such tracks have reduced elasticity, which is particularly important at contact between the sleepers and the stone material. In order to reduce the negative impacts of vibration and thus extend the durability of railway track today, railways increasingly apply concrete sleepers with under sleepers pads. Tests have shown that with the installation of the under sleeper pads it is possible to achieve a quieter passage of the train over the substrates of different stiffness, thus reducing the possibility of damage to the track construction and the vehicle itself.

Keywords: concrete sleeper, under sleeper pads, vibration, railway bridges

1 Introduction

The railway network of the Republic of Croatia consists of slightly more than 2600 km of railways. Within the railway infrastructure there are 545 stations, 1512 railway road crossings, 109 tunnels and 538 bridges. The last newly built railways were put into operation during the 1970s, which ultimately means that most of the built facilities are ready for partial or complete reconstructions and replacements. Apart from the need to invest in the modernization of railway infrastructure, it is also necessary to adjust the instructions and regulations in order to open the way for the introduction and maintenance of new products and more modern technologies. Today's rail traffic is significantly different from when railroads were built. The biggest changes are in the axle load of locomotives and freight being transported. As the technical conditions of transport vehicles on the railways changed, so did the railway infrastructure. Perhaps one of the most sensitive segments of railway infrastructure are bridges. Most of the railway bridges of the Croatian network are steel lattice structures that have been strengthened over time to meet traffic needs. Just as the type of rail traffic has changed, so has the way it is maintained. Today, the maintenance of railway infrastructure is based on as much machine work as possible. To maintain the upper structure of the track, machines are used that maintain the level of the track in such a way that they drive the stone material under the sleepers. The result is that after each mechanical driving, the level of the track rises by a few millimeters to a few centimeters.

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All steel lattice bridges have wooden sleepers that are fixed to the bridge structure, and when maintaining the upper structure of the track they cannot change the height. As a result of the impossibility of changing the height of the level on the steel lattice bridges, we get ramps in front of and behind the bridge, which requires a reduction in train speed in the bridge zone for safety and driving comfort.

Figure 1 Individual processing of wooden sleepers on a steel bridge

The maintenance of the tracks on the structures themselves is required because they are wooden sleepers, each of which is treated separately in order to adjust the height of the bridge and the level of the railway. To change the bridge structure on a facility of about twenty meters of track, a railway closure of almost the same number of hours is required. If the closure is not in one piece for the purpose of dismantling and reassembling the tracks, this venture takes longer, which also means a higher cost.

Figure 2 Attaching wooden sleepers to the steel structure of the bridge

In recent years, it has become a practice that when renovating, reconstructing or replacing dilapidated bridges, care is taken to separate the track grid from the bridge structures. One way is to replace steel lattice structures with trough-shaped reinforced concrete structures or if the spans are larger with trough-shaped steel structures. In this way, continuity in the height of the track is obtained, which significantly affects the ease of maintaining the upper structure of the track and, more importantly, over time there is no need to reduce the speed in the bridge zone. Apart from the change in the shape of the structure, the wooden sleepers are replaced with reinforced concrete.

Figure 3 Steel structure of the bridge

Figure 4 Reinforced concrete span structure of the bridge

2 Vibrations caused by the movement of a railway vehicle

When the vehicle moves on the rails, due to the own weight of the wagon and the locomotive (static load of the track) and the dynamic forces that occur on the contact surface of the wheels and the rail, there are vertical oscillations of the rail. The higher the weight or axle load and speed, the more pronounced the intensity of vibrations that propagate from the source (track) into its environment. At high frequencies, the vibration energy propagates through the air in the form of sound waves (noise), while the vibrations of lower frequencies are transmitted in the form of mechanical waves over the rails to the lower parts of the track structure and then to the surrounding ground.

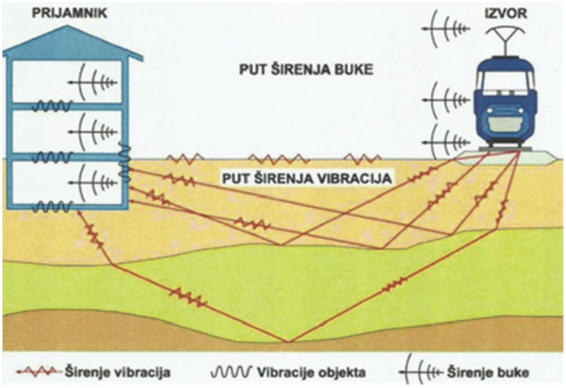

Figure 5 Vibration and noise propagation from railway traffic [1]

2.1 Effect of vibrations on the ballast

The modernization of the railway infrastructure aims to achieve a higher speed of vehicles and increase the carrying capacity of the railway. One of the most common types of classic track structures are certainly tracks with concrete sleepers and a ballast prism made of gravel material. Such tracks, in comparison with constructions made using wooden sleepers, have reduced elasticity, which is especially important at the contact between the sleeper and the ballast material.
With the construction of the railway with the use of concrete sleepers of relatively high stiffness, there were changes in the way of load distribution in the ballast prism just below the sleeper. In general, the gravel ballast prism is the weakest link in the entire track construction because during use, due to dynamic forces on the track, there are lateral dynamic displacements of gravel grains, i.e. mutual compaction and thus gravel degradation. More pronounced and faster degradation and decay of gravel grains is a consequence of the increase in the speed of rail vehicles and their loads and insufficient bending of rails and other elements due to the increased overall stiffness of the track panel.
From the aspect of track maintenance, accelerated track deterioration necessarily requires the implementation of unpopular measures to enable safe and comfortable traffic, which includes: introduction of reduction of train speed, reduction of axle load which negatively affects the transport and capacity of the track) and shortening the regular cycle of maintaining the geometry of the track, thus increasing the cost of maintaining the track.
In order to reduce the negative effects of vibration and thus prolong the durability of the track, today elastic beddings under the rails and elastic rail fastenings are commonly used, and the installation of track support elasticity under the ballast is increasingly used to reduce vibration transmission from the ballast to the lower rail structure, i.e. foundation soil. The disadvantage of such supports is the relatively high price and difficulties in installation (it is difficult to compact the ballast material). Recently, as an alternative or additional possibility to increase the elasticity of the track structure, the installation of a bedding made of elastic, soft material between the sleepers and the ballast has stood out.

2.2 Elastic beddings on the sleepers

The first application of elastic beddings attached to the lower surface of the sleeper was carried out on the Swiss Railways (SBB) in 1986. This solution proved to be better compared to the elastic beddings under the ballasts because it prevented the transition of vibrations to the structure already in the upper parts. The basic function of beddings is to reduce the effect of non-uniform track stiffness on the contact forces and to increase the area over which the sleepers transfer these loads to the ballasts.

Figure 6 Elastic beddings under the concrete sleeper [1]

The installation of beddings reduces the resonant frequency of the track panel and thus reduces the transmission of vibrations from the panel to the gravel material of the ballast and the lower structure of the track. Also, by reducing the vibrations transmitted between individual grains of gravel material, it is possible to significantly reduce its wear, which directly affects the increase in the maintenance period of the ballast.

3 Application of concrete sleepers with elastic beddings in the bridge zone

Due to the stiffness, the existing tracks are built on an inhomogeneous base. Sudden changes in vertical stiffness along the track route are in the zones:
• switch
• curves of small radii
• at road crossing points
• and in the zones of bridges or viaducts.

Significant dynamic forces (shocks) occur in these places, which manifest as an uncomfortable jerk of the train while running and result in accelerated wear of the ballast under the sleepers. In addition, the service life of structures and rail vehicles is reduced.
To prevent unwanted consequences on bridges, concrete sleepers with beddings are used to mitigate sudden changes in bedding stiffness. Tests have shown that by installing beddings on a transition stretch of sufficient length, it is possible to achieve a smoother passage of the train over surfaces of different stiffness, which reduces the possibility of damage to the track structure and the vehicle itself. Transitional stretches are 20 to 30 meters long with beddings of slightly higher stiffness than on the building itself where soft stiffness beddings are installed.

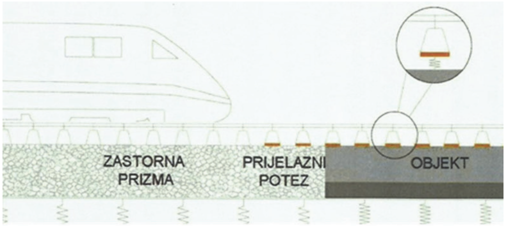

Figure 7 View of transition zones [1]

In the past ten years, at the Department of Railways at the Faculty of Civil Engineering in Zagreb, research has been conducted on the ability to dampen vibrations from individual components of track construction. For testing purposes, a testing site was made consisting of a 30 cm thick slab on which two test structures were laid, each of which consisted of two rails 60 EI, 1.20 m long, fastened with elastic rail fastenings SKL-I for two concrete sleepers PB -85-K. Vibration measurements on a concrete base with and without elastic beddings and vibration effect measurements on the ballast material under concrete sleepers with and without elastic beddings were performed at the test site.

Figure 8 Vibration measurement on a concrete base without elastic beddings [1]

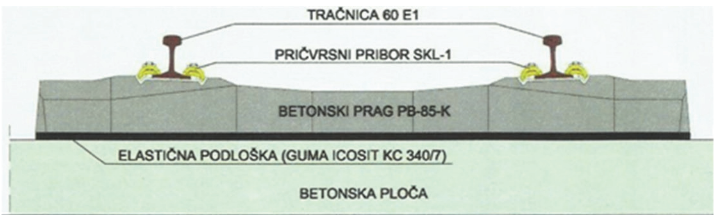

Figure 9 Vibration measurement on a concrete base with an elastic bedding [1]

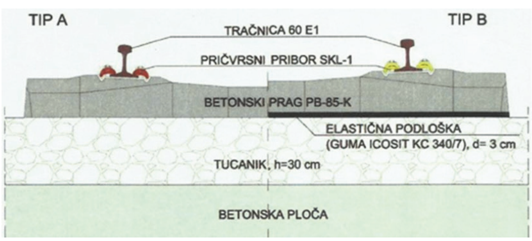

Figure 10 Measurement of the effect of vibration on the ballast material below the concrete sleepers with and without elastic beddings [1]

All the obtained measurements showed that the use of elastic beddings significantly reduces the spread of vibrations on the concrete slab, or on the ballast material. However, the results obtained were obtained on a testing site where the vibrations were caused by a weight and not a rail vehicle. The next step in the vibration propagation test should be performed on the test section where the results obtained would give a true picture of the vibration reduction effect using elastic beddings.

4 Conclusion

By changing the type of bridge construction, it is much easier to maintain the upper structure of the railway on bridges and viaducts, but with the new solution there are new problems of their maintenance. The installation of concrete sleepers with beddings in the area of bridges prolongs the life of the track structure and the facility itself, which ultimately means cheaper maintenance. Tests performed at the Faculty of Civil Engineering in Zagreb should be just the beginning of understanding the meaning of installing elastic beddings under concrete sleepers not only in areas around bridges, but also on other structures (railway crossings, switches, tunnels…). Due to environmental requirements, there are fewer and fewer wooden sleepers on the market that, due to their elasticity, meet the requirements of railways where there is no buffer layer. The results obtained at the test site are a good indicator to continue with the tests on the test section with real load and to examine the possibility of complete replacement of wooden with concrete sleepers with elastic beddings.
Since larger investments in railway infrastructure are planned, it is necessary to invest as much effort as possible in the education of designers, manufacturers, contractors… in order to keep pace with already tested products and well-established technologies for railway infrastructure maintenance.

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