DURABILITY OF REINFORCED-CONCRETE TRACK SLEEPERS

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Abstract

During the regular track inspection of railway lines in various parts of the Republic of Croatia, cracks were found on prestressed reinforced concrete sleepers. These sleepers were installed between 1990 and 2003 in different parts of Croatia, on different surfaces, on railway lines with different intensity and for different types of transport. In order to determine the cause of damage and to estimate the remaining service life of the installed sleepers, the damaged and intact concrete sleepers need to be examined and analyzed. The results have to be compared with the experiences of other railway administrations that have similar problems. Based on the obtained results, it is possible to estimate the service life of concrete sleepers depending on the conditions during operation. It is also possible to estimate how long the damaged sleepers can function as part of the railway.

Keywords: track, track maintenance, concrete sleepers, service cycle concrete sleepers, damaged concrete sleepers

1 Introduction

In railway maintenance, special attention is always paid to track maintenance, which is defined as a structure made of elements of the railway superstructure [1]. It is allowed to install in the tracks wooden sleepers, reinforced concrete sleepers and in exceptional cases steel sleepers [2]. The main purpose of railway sleepers is [1]:

- to evenly carry the load caused by railway vehicles
- to ensure the support and stability of the track base and the track system
- to dampen the railway vibrations and reduce the noise caused by the contact between the wheels of the railway vehicles and the track.

In Figure 1 we can see the prescribed cross-sectional profile of the ballast shoulder of the track in the concrete sleepers [2].

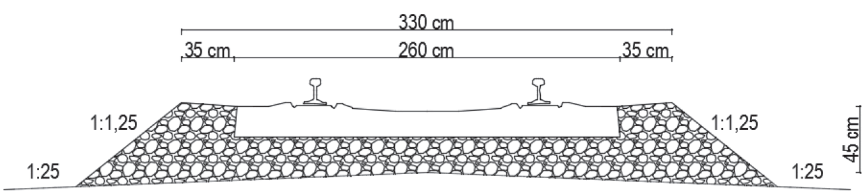

Figure 1 Cross-section profile [2]

The most common installed type of one-piece prestressed concrete sleeper is B70 with elastic rail system. Reinforced concrete sleepers shall not be installed in the following situations/locations: unstable substructure, rail joints, 30 meters before and after bridges in open construction, on turnouts and crossings, and steel bridges. The installation of both wooden and concrete sleepers is prohibited [2]. The advantages and disadvantages of reinforced concrete sleepers are shown in Table 1.

Table 1 Advantages and disadvantages of the reinforced-concrete sleepers [1]

Advantages of the concrete sleepers:	Disadvantages oof the concrete sleepers:
- Large mass - Typical and fast production - High tenacity - Long-lasting durability - Weather resistance - Ecologically acceptable	- Less elasticity than wooden sleepers - Sensitivity to mechanical deterioration regarding the derailment of the railway vehicles - High dynamic load on the track ballast - More complex maintenance during which the track mechanization is obligatory

2 Technical characteristics of the one-piece concrete sleeper

Reinforced concrete sleepers have been installed in railway tracks since the middle of the 20th century. Currently, three types of reinforced concrete sleepers are manufactured in EU countries: One-piece concrete sleepers (HRN EN 13230-2), two-component sleepers (HRN EN 13230-3) and sleepers for turnouts and crossings (HRN EN 13230-4). Looking at the use all over the world, especially in Japan, the use of reinforced concrete sleepers should also be highlighted.

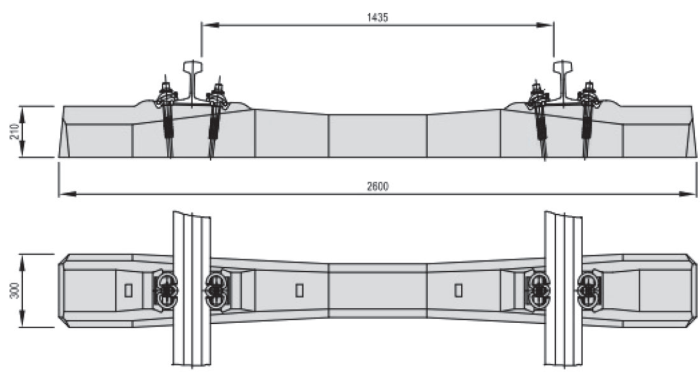

Figure 2 Concrete sleeper type B70 [3]

Elastic track fastening device for a prestressed reinforced concrete sleeper consists of: Sleeper screw with washer - 4 pieces, elastic spring clip - 4 pieces, synthetic corner tiles - 4 pieces, synthetic sub-rail pad - 2 pieces, plastic screw dowels - 4 pieces.

Figure 3 Elastic track fastening device for one rail seat section [4]

3 Analysis of different types of crackings

Longitudinal cracks on concrete sleepers due to exploitation have been found on certain railway sections. The railway sections in question have different ground conditions, they are exposed to different climatic conditions and different volumes and types of railway traffic operate on these sections. Longitudinal cracks, which can be found on concrete sleepers, are becoming increasingly common on many railway lines, both in Europe and worldwide. These cracks run parallel to the longitudinal axis of the sleeper between two fixing points. The location where the cracks occur is the position of the plastic dowel. Two types of cracks were identified during the analysis:

- Type 1: longitudinal cracks along the dowels (connection between a rail and a sleeper), maximum in length 30 cm on both sides, width ≤ 0.5 mm; the cracks are uneven and non-linear.
- Type 2: longitudinal cracks along the entire length of the sleeper, width ≥ 1 mm; the cracks are non-uniform and non-linear

Figure 4 TYPE 1 cracking

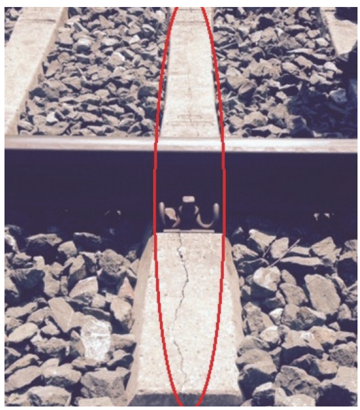

Figure 5 TYPE 1 cracking

3.1 Greek railway experience

During the reconstruction of the Korint – Tripolis – Kalamata section in 2007, longitudinal cracks were detected on concrete sleepers. As a result, an analysis was carried out and the damaged sleepers were inspected and tested. Most of the cracks had spread over the entire height of the sleeper. They started at the point of attachment and widened towards the end of the sleeper [5]. Figure 6 shows longitudinal cracks on the concrete sleeper along the entire cross-sectional plane.

Figure 6 Longitudinal cracking on the concrete sleeper [5]

After observing the problem, an analysis was performed. After analysis, it was determined that the cause of the cracks was high tightening torque of the bolts. It was proven that a tightening torque of more than 450 Nm in combination with a pre- existing pre-stress can cause the crack in the concrete sleepers and the cracks can occur. It is assumed that the cause of the cracking was the failure of the torque measuring device [5].

3.2 Iranian railway experience

After most of the prestressed concrete sleepers were replaced in 2011, the longitudinal cracks were discovered in the same year. The cracks are found where the screws are, and they widen towards the middle and end of the sleeper. Some of the cracks were noticed before the railway was opened to traffic [6]. In Figure 7, the cracking can be seen at the rail bearing point, i.e. the cracking starts in the dowels that were installed in the sleeper.

Figure 7 Longitudinalan cracking in the concrete sleeper

After the problem was discovered, a test was performed on the sleeper, parallel with numerical simulations. After the test, it was found that reinforced sleepers have a higher resistance to longitudinal cracking, as they have better properties than the non-reinforced ones when injected with a larger amount of chemical agents. It was also found that the use of transverse reinforcement bars provided adequate tensile strength to the sleepers. Thus, the longitudinal cracks could be brought under control [6].

4 Reasons for degradation of the concrete sleepers

Due to the degradation of sleepers on certain railway sections before their predicted service life, a large amount of concrete sleepers need to be replaced, which is a lengthy and expensive process [7]. It is also important to know the degree of damage of certain sleepers and the potential possibility of their further use. There are many factors that affect the durability of concrete sleepers. The most common are defects and aging of the fastening system, track ballast in poor condition, and cracking due to dynamic loading [8]. Longitudinal cracking can also be caused by the initial improper loosening of the clamp after the prestressing force is applied, resulting in some prestress in the concrete. In order to minimize high tensile stresses in concrete, compressive stresses are introduced into the concrete from outside by means of prestressing steel, so the value of prestressing force is one of the most important parameters in the design of sleepers. In manufacturing, the prestressing process is carried out before the concrete hardens [9]. Due to prestressing, it is very important to use high strength concretes for the sleepers (at least 50 N/mm2) [10].The dynamic loads to which the concrete sleepers are subjected arise from the interaction of the vehicle wheels and the rails. In practice, these loads reach large amounts when there are irregularities in the wheels, rails, attachments, and vehicle speed. Such a load is represented as a periodic impact load that varies in time [10]. Since the sleeper in the track interacts with other elements of the superstructure and substructure, significant impacts on the sleeper have a track ballast, which has its prescribed dimensions. Very often, the track ballast is contaminated, does not have a satisfactory grain size and is improperly compacted. This has a negative effect on the occurrence of vibrations in the sleeper [11]. The environment in which the sleeper is located also has a significant effect on the damage and reduced service life of the concrete sleeper. This refers to influences such as rain, sun, freezing and thawing, temperature fluctuations, various chemical substances in the soil and air that can damage the structure and reinforcement of the concrete as well as accelerate the degradation of the sleepers. These external influences also affect other parts of the track, which affect the durability of the sleepers [8].

5 Conclusion

The occurrence of longitudinal cracking is a type of sleeper degradation which is present in many railway administrations around the world. This problem has been found to be present all over the world, with various possible causes for the occurrence of longitudinal cracking being discovered. It has been found that the reasons for the occurrence of cracks can be many, some of which include errors in production and transportation, improper installation or installation on an improperly prepared subgrade, and inadequate maintenance of the track or damage caused by faulty rolling stock. To determine the cause of cracks, it is necessary to perform static and dynamic tests on damaged and undamaged sleepers, as well as tests on the material from which the sleepers are made. In addition to the planned tests, it is advisable to develop a numerical model that would serve to predict the occurrence of cracks on concrete sleepers depending on the effects of various external influences.

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