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PRESTRESSED CONCRETE SLEEPER UNDER EXTREME LOADING CONDITIONS

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Abstract: *Prestressed concrete sleepers are among the most common structural components of the railway tracks. Nowadays, the majority of railway sleepers are made of prestressed concrete. During their service life, the sleepers are subjected to extreme loading conditions, which may drastically reduce the span of their service life. This paper focuses on the optimized design of prestressed railway sleeper subjected to extreme loading conditions, which represented here by the impact of a flat wheel and by the cyclic loading.*

Keywords: ***Extreme loading, prestressed concrete sleeper, optimization, cyclic loading, fatigue*.**

1. Introduction

The classical railway track consists of the rails, fasteners, sleepers, ballast and underlying subgrade. The railway sleepers lie on the ballast transversally to the rails, which supports and holds them in place, and provides drainage and flexibility. The sleepers transfer the loads from rails to the ballast and subgrade, hold the rails to the correct gauge, restrain longitudinal and lateral rail movements, and provide strength and stability to whole track structure. It is obvious that the sleepers are subjected to extreme loading conditions and their design should be provided with high attention.

2. Loading of railway sleepers

The whole railway track is subjected to static and dynamic load, which is caused by train transportation. The design static wheel load per rail seat for standard railway tracks is 125 kN. But it should be noted that the railway tracks often suffer from extreme loading conditions. The extreme loading is attributed to the wheel and rail abnormalities, which are, for example, the flat wheels, wheel corrugation, out-of-round wheels, dipped rails, etc. These defects can cause loading of a very high magnitude but short duration and the occurrence of such loading is of low probability during the design life of the sleeper (Kaewunruen & Remennikov, 2009). The magnitude of the dynamic impact loads per rail seat varies from 200 kN up to 750 kN (Remennikov & Kaewunruen, 2008). These forces may cause cracking and failure of the sleeper (Sýkorová, et al., 2011).

Railway sleeper is a structural element which is subjected to cyclic loading during its entire service life. The cyclic loading causes fatigue of concrete, which results in permanent progressive changes in the structure of the material. These changes can cause crack, or micro-crack, propagation which consequently reduces stiffness of the structure, which in the extreme case can lead to fatigue failure.

3. Numerical analysis of railway sleeper

The resulting shape of the sleeper was obtained by the optimization of the shape of the standard B70 prestressed concrete mono-block sleeper. The prestressing force and the position of prestressing wires are then determined accordingly for the optimized shape of the sleeper.

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3.1. Optimized design of the concrete sleeper for the standard load and the impact of flat wheel

The problem is divided into two cases. The first case is related to the design of the sleeper to withstand the standard load of 125 kN per rail seat. The second case deals with the design of the sleeper to withstand the load of 400 kN per rail seat, which represents the impact of the flat wheel. The necessary prestressing reinforcement is provided with the identical prestressing wires with the proof test of 1860 MPa. The sleeper with standard load of 125 kN on both rail seats is prestressed with 10 wires with the diameter of 6 mm. The sleeper designed for impact load of 400 kN on both rail seats is prestressed with 12 wires with the diameter of 8 mm. The 28-day compressive strength of concrete used in the analysed sleeper must be greater than 50 MPa.

3.2. Cyclic loading

The railway sleeper is subjected to cyclic loading which causes fatigue of concrete. The analysis of the prestressed concrete sleeper under fatigue load is done for the sleeper with standard load of 125 kN on both rail seats. The most important characteristic when analysing the fatigue behaviour of concrete is the decrease of stiffness, which is calculated here by using fatigue damage function (Foglar, 2008; Sýkorová et al., 2008). This function depends on the total number of load cycles and the load level. The total number of load cycles which the prestressed concrete railway sleeper can resist during its service life, was determined by formulae in Eurocode 2 (CEN, 2005) as 80 millions. With respect to the maximum and minimum compressive stresses in the cross section under the rail seat, the load level is determined as 0.44. The modulus of elasticity decreases rapidly during the first few hundred thousands of load cycles and then again at the end of its service life. During the first 10 per cent of all load cycles the mean value of the modulus of elasticity decreases from the initial value of 37 GPa to 26.2 GPa. Such reduction of stiffness results in greater deformations and even in cracking and thus in reduction of the expected service life.

4. Conclusions

This paper presented an analysis of prestressed concrete railway sleeper subjected to two types of extreme loading conditions. Railway sleeper can suffer during its service life from impact load caused by flat wheels. Therefore, the standard shape of the sleeper known as B70 was optimized and the prestressing force designed so that it can withstand the impact load of 400 kN instead of the ordinary 125 kN per rail seat. Railway sleeper is also structure which is subjected to cyclic loading. Cyclic loading of the railway sleepers commonly exceeds 80 millions of cycles during their service life which is commonly more than 40 years. Therefore, the optimized railway sleeper was analysed for the effect of cyclic loading which causes fatigue of structural elements. For the analysis of reduction of stiffness during the cyclic loading was used cyclic damage function.

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References

Eurocode 2 - Design of Concrete Structures - Concrete Bridges - Design and detailing Rules (2005) CEN.

Foglar, M. (2008) *Strain development under cyclic loading*. Ph. D. Thesis, CTU in Prague, Prague.

Kaewunruen, S. & Remennikov, A. M. (2009) Progressive failure of prestressed concrete sleepers under multiple high-intensity impact loads. *Engineering Structures*, 31, pp.2460-2473.

Remennikov, A. M. & Kaewunruen, S. (2008) A review on loading conditions for railway track structures due to wheel and rail vertical interactions. *Progress in Structural Engineering and Materials*, 15, pp.207-234.

Sýkorová, J., Bártová, J. & Štemberk, P. (2011) Analysis of Prestressed Concrete Sleeper under Extreme Loading Conditions, in: *Mechanika 2011 - Proceedings of the 16th International Conference*, Kauno technologijos universitetas, Kaunas, pp.282-286.

Sýkorová, J., Foglar, M. & Štemberk, P. (2008) Fatigue of reinforced concrete bridges with influence of deterioration of concrete, in: *Microstructure Related Durability of Cementitious Composites – Proceedings of the First International Conference*, Bagneux: Rilem Publications s.a.r.l., pp.825-832.