International Conference on Case Histories in Geotechnical Engineering

(2008) - Sixth International Conference on Case Histories in Geotechnical Engineering

Aug 11th - Aug 16th

Investigation on the Causes of Longitudinal Cracks on Prestressed Monoblock Railway Sleepers of Metric Gauge of the Greek Railway Network

Spyros Tsoukantas
National Technical University of Athens, Greece

Konstantinos Tzanakakis
EDISY S.A., Greece

Danai Spyropoulou
EDISY S.A., Greece

Petros Panopoulos
EDISY S.A., Greece

Manto Mintzia
EDISY S.A., Greece

Recommended Citation

Tsoukantas, Spyros; Tzanakakis, Konstantinos; Spyropoulou, Danai; Panopoulos, Petros; and Mintzia, Manto, "Investigation on the Causes of Longitudinal Cracks on Prestressed Monoblock Railway Sleepers of Metric Gauge of the Greek Railway Network" (2008). *International Conference on Case Histories in Geotechnical Engineering*. 7.
http://scholarsmine.mst.edu/icchge/6icchge/session08c/7

6th International Conference on
Case Histories in Geotechnical Engineering, Arlington, VA, August 11-16, 2008

INVESTIGATION ON THE CAUSES OF LONGITUDINAL CRACKS ON PRESTRESSED MONOBLOCK RAILWAY SLEEPERS OF METRIC GAUGE OF THE GREEK RAILWAY NETWORK

Dr. Spyros Tsoukantas
Ass. Professor
National Technical University of Athens –
GREECE 10682

Konstantinos Tzanakakis
Track Director
EDISY S.A.
GREECE 10444

Danai Spyropoulou
Head of Bridges Department
EDISY S.A.
GREECE 10444

Petros Panopoulos
Head of Athens Maintenance Department
EDISY S.A.
GREECE 10444

Manto Mintzia
EDISY S.A.
GREECE 10444

ABSTRACT

Recently (2007), during the rehabilitation of the Greek Railway Organization (OSE) line Korinth – Tripolis – Kalamata, longitudinal cracks have been observed in some of the prestressed monoblock sleepers of metric gauge used in this line. In this paper the methodology adopted by the committee that investigated the causes of this phenomenon is presented, e.g. on site investigation of the damaged sleepers, investigation of the probable causes of the cracks during the production of the sleepers (faulty concrete grade – faulty prestress level e.t.c.), together with theoretical considerations which, all together, led to the cracking of the sleepers.

INTRODUCTION

Although the Main Railway net of the Greek Railway Organization (O.S.E.) is based on line of normal gauge (1,435m) using mainly prestressed Monoblock Concrete sleepers, it has been decided by the same organization to keep the metric gauge (1,00 m) for the existing secondary Peloponnesus line and rehabilitate it totally by replacing (between else) the existing wooden sleepers by suitable prestressed Monoblock concrete ones. During the rehabilitation works in the section between KM 102+100 and KM 108+000 (4700 sleepers) as well as between KM 152+400 and KM 160+000 (1100 sleepers), the supervision team of EDYSI of the O.S.E. observed longitudinal cracks in 24 sleepers. In what follows the methodology adopted by the Authors is described which led to the understanding of the causes of the cracking of these sleepers.

CHARACTERISTICS OF THE USED SLEEPERS AND THEIR FASTENINGS

Geometry

The geometrical characteristics of the sleepers are presented in Fig. 1 (half sleeper). These sleepers have been produced in Greece according to Leonard Moll technology, foreseen for line of metric gauge.

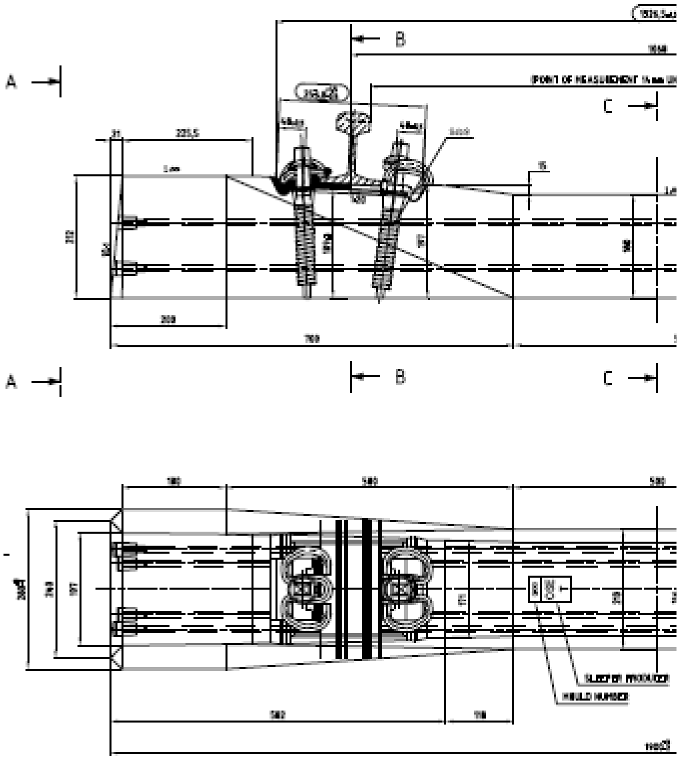


Fig. 1. Half sleeper

Material Properties

Concrete: C 50/60
characteristic strength: f_{ck} = 50 MPa
mean value of comp. strength: f_{cm} = 58 MPa
secant modulus: E_{cm} = 37.000 MPa
flexural tens. strength (7 days): $f_{ct,fl,7} \geq 5.5$ MPa
admissible flex. tens. strength: $f_{ct,fl,dyn} = 3.0$ MPa

Prestressing steel: St 1375/1570, very low relaxation
diameter: $\varnothing = 9.5$ mm
area of cross section: $A_p = 70.9$ mm^2
charact. tensile strength: f_{pk}=1570 MPa
char. 0.1% proof – stress: $f_{p0.1k}$=1375 MPa
modulus of elasticity: E_p = 205.000 MPa

Prestressing force:

- Initial prestressing force: $P_{m,0} = 305.5$ kN
- Total loss of presstress : $\Delta P_t = 0.195\ P_{m,o}$

Fastening System

The Vossloh rail fastening system W14 has been used with the tension clamp SKl 14 as shown in Fig. 2.

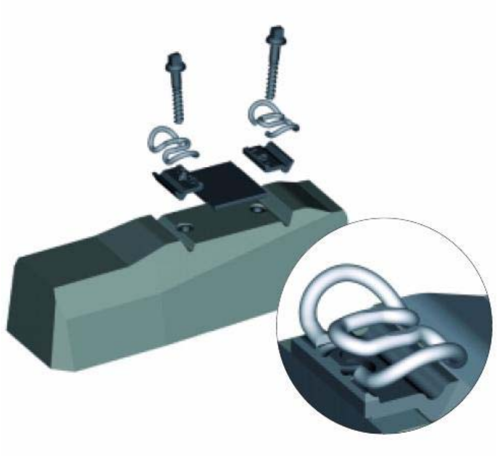


Fig. 2 . Rail Fastening system W14

According to Vossloh recommendation the tension clamp is correctly fitted as soon as the middle bend of the clamp is in contact with the rib of the angled guide plate by tightening of the sleeper screw (max. permissible air gap: 0.5 mm). This is reached at a tightening torque of approx. 200 Nm (see Fig. 3).

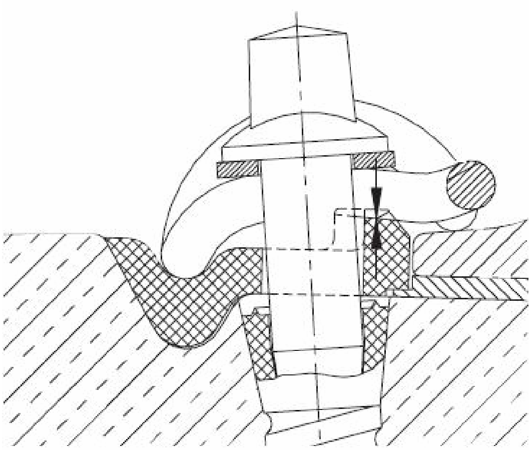


Fig. 3. Tension clamp SKl 14-Fitting instruction

TYPES OF CRACKS IN THE DAMAGED SLEEPERS

In Fig. 4, 5, 6 and 7 some cracked sleepers are shown, as found by the supervision team during the rehabilitation works, provisorely fastened, before performing the welding of the rails, according to the CWR procedure. Almost, all cracks went through the whole height of the sleeper. As it can be seen, cracks started from one of the rail seats and have been developed towards the end of the sleeper having in the same time the tendency of developing also in the area of the sleeper between the two railseats. In Fig. 8 one damaged sleeper is shown which was intentionally forced to develop full longitudinal cracks and in Fig. 9 two other sleepers are shown which were separated in two longitudinal parts each, in order to observe the situation of the profile between the sleeper screws and the surrounding concrete.

Fig. 4

Fig. 5

Fig. 7

Fig. 6

Fig. 8

Fig. 9.

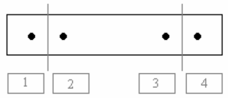
METHODOLOGY KEPT BY THE AUTHORS IN ORDER TO UNDERSTAND THE REASONS WHICH LED TO THE CRACKS OF THE SLEEPERS

First step (on site investigation)

Photos of the damaged sleepers have been taken and their age has been identified. All damaged sleepers had an age ranging between 3 to 20 months.

The existing value of tightening torque of the sleepers screws was checked. For this reason random checks on site on 37 sleepers (other than the damaged ones) have been performed in order to find the real values of the applied tightening torque on each sleeper in this stage of the line. In Table 1 a characteristic part of the results of these tests is presented. As it can be seen from this Table, almost in all cases the applied tightening torque was always greater than 200 Nm, (value which is prescribed by Vossloh for this fastening system).

Table 1. Existing value of tightening torque

s/n	km	Factory Data	Tightening torque			
		Production date of the sleeper	 sleeper			
1	102+806	15/11/2004	360	280	360	380
2	102+915	16/2/2007	360	360	340	360
3	103+009	20/2/2007	360	340	360	360
4	103+074	30/6/2005	380	300	300	300
5	103+221	16/2/2007	380	300	280	340
6	103+409	16/2/2007	240	280	340	300
7	103+590	29/6/2007	320	260	200	220
8	103+750	28/6/2007	200	240	300	260
9	103+916	11/1/2007	280	240	240	280
10	104+175	16/11/2007	400	300	280	320
11	104+320	4/1/2005	360	360	400	340
12	104+321	Not existing	400	300	300	380
13	104+446	28/6/2005	300	280	360	320
14	104+608	14/2/2007	340	300	340	240
15	104+797	29/6/2005	280	220	220	240
16	108+878	Not existing	420	300	340	400
17	108+890	27/9/2004	420	320	320	400
18	114+942	Not existing	320	440	320	340

The behaviour on cracking on two sleepers of different ages to the applied tightening torque was checked.

Sleeper of about 2 years of age. It has been observed that by increasing the tightening torque from 300 Nm to 680 Nm, in one railseat, sliding of the sleeper screws started on about 525 Nm and further this screw became inactive for about 680 Nm, while, in the other railseat the relevant screws became inactive for about 660 Nm. The sleeper did not crack considerably except from some almost invisible longitudinal cracks.

Sleeper of about 2 months of age. It has been observed that, by increasing the tightening torque from 300 to 600 Nm, almost in both railseats sliding of the sleeper screws has been observed in about 440 Nm, while in values of tightening torque of 550 Nm to 600 Nm the sleeper developed visible cracks, along its length.

Second step – Investigation of the production of the sleepers

Systematic investigation on the production factory of the sleepers showed that:

- the concrete grade during the production was always $f_{ck} \geq 50MPa$
- the concrete grade of the damaged sleepers under the initial prestress was also always $f_{ck} \geq 50MPa$
- the applied curing method was proper
- the procedure of the application of the prestress force on the sleepers and its value were correct
- there were not observed malfunctions during the procedure of tightening the sleepers screws.
- the slopes of the screws inside the sleepers were according to the requirements

In order to check the slopes of the screws some random ready sleepers were cut accordingly. The requirements of these slopes are shown in Fig. 10, while in Fig. 11 the real condition of the slopes is presented which fits with the requirements.

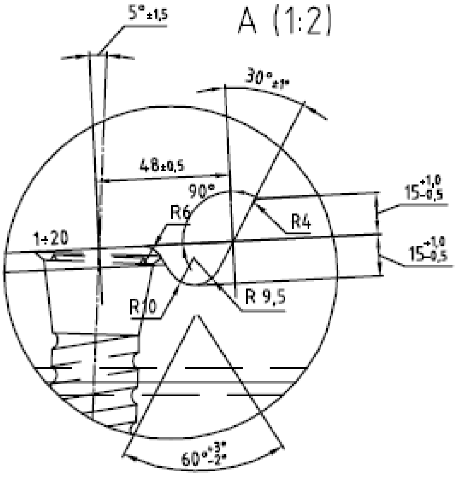


Fig. 10.

Fig. 11.

<u>Third step of investigation – Theoretical considerations</u>

<u>Estimation of the degree of prestress in the railseat (l_{rs} = 41.6 cm from sleeper's end).</u> That is estimation of the transmission length, l_{pt}, over which the prestressing force (P_o) is fully transmitted to the concrete, and comparison with l_{rs}.

To this end for the estimation of, l_{pt}, Eurocode 2 [§8.10.2] has been used as follows:

$l_{pt2} = 1.2\ l_{pt}$

$l_{pt} = a_1 \cdot a_2 \cdot \Phi \cdot \sigma_{pmo}/f_{bpt}$

$f_{bpt} = n_{p1} \cdot n_1 \cdot f_{ctd}$

$f_{ctd} = f_{ctm} \cdot 0.7/\gamma_c$

where :

σ_{pmo} = 1077.1 MPa (according to the design of the sleepers)

$a_1 = 1.0$

$a_2 = 0.19$

$\Phi = 9.5$

$n_{pi} = 3.2$

$n_1 = 1.0$

f_{ctm} = 4.10 MPa

Thus l_{pt2} = 381.04 < 416 mm

This means that in the area of the railseats, the prestress force is fully developed (see Fig. 12).

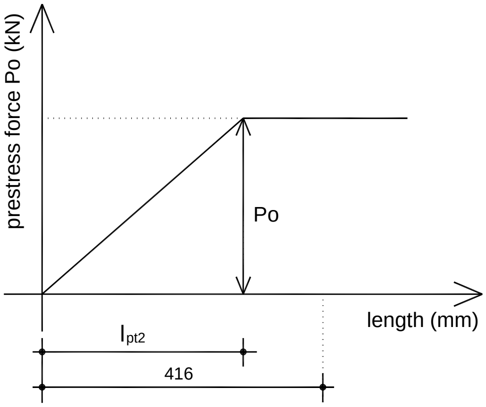


Fig. 12.

<u>Qualitative aspects about the stress conditions in the interface concrete – sleeper screw under tightening torque.</u> In Fig. 13 the geometrical characteristics of a sleeper screw and its plastic cover are presented. In Fig. 14 the stress conditions of the concrete between the steel ribs are shown qualitatively. According to Fig. 14, it may be expected that in the moment of the pull-out of the sleeper screw and further, a lateral expansion of the surrounding concrete takes place causing an uncontrollable lateral tension state on the concrete, which surrounds the screw.

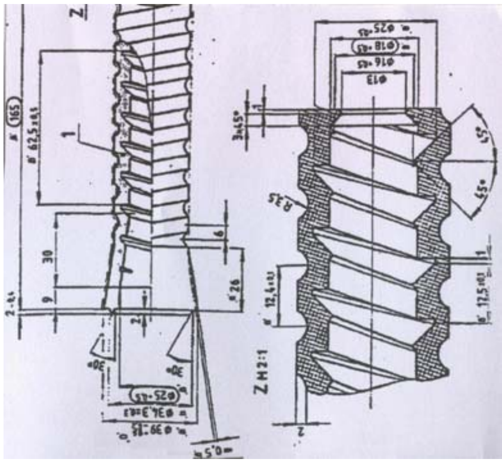


Fig. 13.

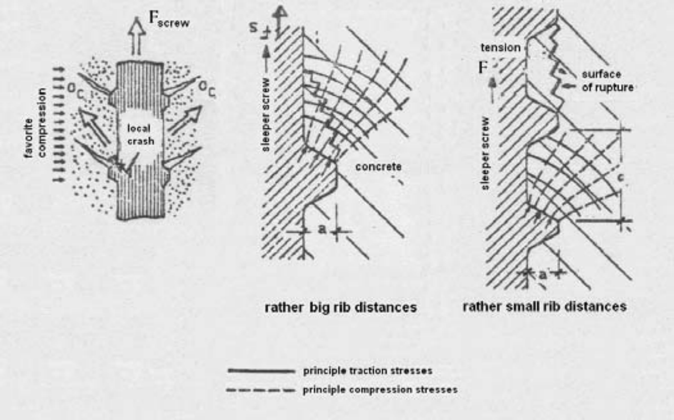


Fig. 14. Qualitative representation of the stress conditions of concrete between steel ribs

A finite element approach has been also performed to get an idea about the multiaxial stress conditions in the concrete area around the sleeper screws, due to the simultaneous action of the presstress force and the screw actions.

To this end:

- the sleeper has been modelled using volume finite elements representing concrete grade C50/60
- the longitudinal prestress was modelled through truss elements able to recognize the prestress force
- the sleeper screws were also modelled using truss elements with force according to the level of the tightening torque. The forces corresponding to each level of tightening torque were estimated by suitable tests.

In Fig. 15 a representative picture of the stresses around the screw is presented indicatively.

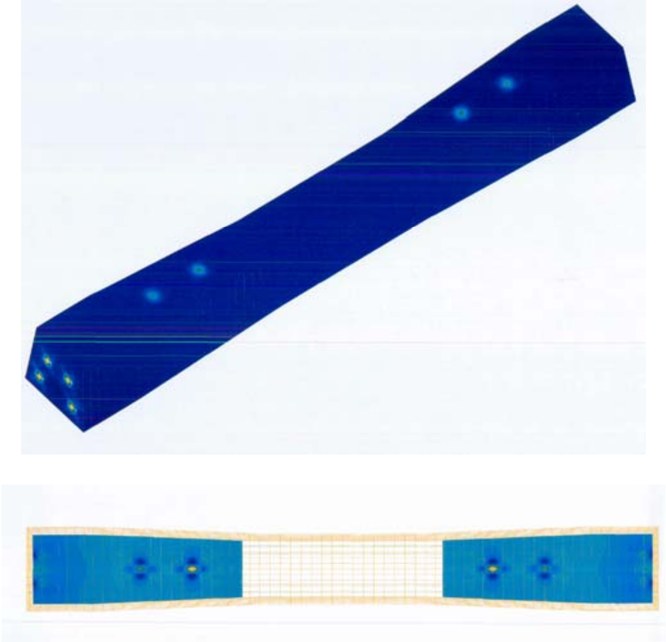


Fig. 15.

In Table 2 the relationship between the tightening torque and the principle tension stresses is shown derived from the above semitheoretical approach.

Table. 2.

Tightening torque (Nm)	Tensile principle stress (MPa)
150	1.88
200	2.42
250	3.46
300	3.89
350	4.56
400	4.98

CONCLUSIONS

According to all the above, the Authors believe that the sleepers cracked longitudinally due to the high level of the tightening torque (>>200 Nm) that was applied to the sleeper screws. It seems that values of the tightening torque higher than about 450 Nm (depending also on the age of the concrete) may provoke sliding of the screws which together with the existing prestress stresses lead to the cracking of the sleepers.

REFERENCES

EUROCODE 2 : [2002] *"Design of concrete structures Part 1 General rules and rules for buildings, prEN 1992-1-1"*