Proceedings of 14th International Conference. Transport Means. 2010.

Some features of behavior of acoustic emission signals at dynamic bench tests of prestressed concrete sleepers

A. Urbahs[*], M. Banov[**], V. Turko[***], S. Bratarchusk,[****] N. Khodos[*****]

[*]*Riga Technical University Institute of Transport Technology, Riga, Latvia, Lomonosova 1 Bldg. VE-mail: Aleksandrs.Urbahs@rtu.lv*
[**] *Riga Technical University Institute of Transport Technology, Riga, Latvia, Lomonosova 1 Bldg.VE-mail: mukharbij@inbox.lv*
[***]*SIA "Aviatest LNK", Riga, Latvia, Rezeknes 1,E-mail: vladislav_turko@mail.ru*
[****]*Riga Technical University Institute of Transport Technology, Riga, Latvia, Lomonosova 1 Bldg. E-mail: informatika@inbox.lv*
[*****]*Riga Technical University Institute of Transport Technology, Riga, Latvia, Lomonosova 1 Bldg. E-mail: info@prommet.info*

Abstract

To quantify the fracture loads of railway prestressed concrete sleepers the dynamic bending tests were carried out . In the course of tests the initial (first) crack, the crack opening and crash event of presstressed monobloc sleepers were registered by a Method of Acoustic Emission (MAE). It is shown that MAE allows to fix the beginning of cracking and evolution of cracks earlier, than other instrumental and visual inspection. During visual inspections (no longer than 5 min between the dynamic loading steps) for crack shores opening measurement the cracks are “healing”. This effect it is clearly seen by the Acoustic Emission signals movement on the next loading step. The cracs "curing" time is reduced from one load step to another. The received results will allow to define further quality of clutch of armature with concrete, and as consequence, quality of pulling together efforts of any preliminary intense reinforced concrete designs
KEY WORDS: *prestressed monobloc railway sleepers, method of acoustic emission, dynamic bending loading, the effect of cracks“healing”*

1. Introduction

Reinforced concrete is a combination of two different in their mechanical characteristics of materials: iron (steel) and concrete. They worked together in the design as a monolithic whole. Effectiveness of joint work is so different from existing material and it is possible and profitable thanks to their properties as follows:

- The availability of quality of the adhesion between two materials. Thus, during the solidification of concrete is firmly adheres to steel. Therefore, under the influence of external forces, both material, working together, receive the same strain
- Steel and concrete have nearly equal coefficients of the linear expansion (concrete, depending on the type of fillers $\alpha \approx 1{,}0 \times 10^{-5}$, for steel, $\alpha = 1{,}2 \times 10^{-5}$.) Therefore, temperature changes in a composite material having a small internal pressure, precluding the emergence of dangerous strains.
- Concrete, as a poor conductor of heat protects steel from sudden temperature changes.
- The concrete protects the steel from corrosion, ensuring the safety of steel that has been confirmed for demolition of old concrete structures Thus, the use of concrete is achieved favorable conditions of work of both materials. Moreover, the concrete takes mainly compressive stress, and steel - stretching.

Reinforced concrete structures are divided into ordinary and prestressed. One of the main drawbacks of conventional reinforced concrete structures is the formation of cracks under load, not even reaching the performance. The desire to address this shortcoming has led to the creation of so-called prestressed structures. The basic idea of these constructions is that by artificially pre-compression of concrete in the construction field, where the load causes tensile stresses, concrete has an opportunity guaranteed to work in operating loads without the fear of premature formation of cracks in these locations. For such structures are prestressed monoblock railway sleepers.

2. The object of study.

Modern concrete sleepers - are prestressed concrete beam, reinforced by high tensile steel wire bars with a diameter of 3,14 mm. Nominal number of wires in a tie: 44.

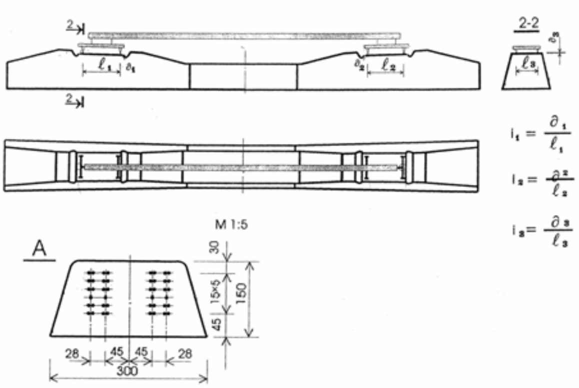

Fig.1 The Sleeper’s Draw.

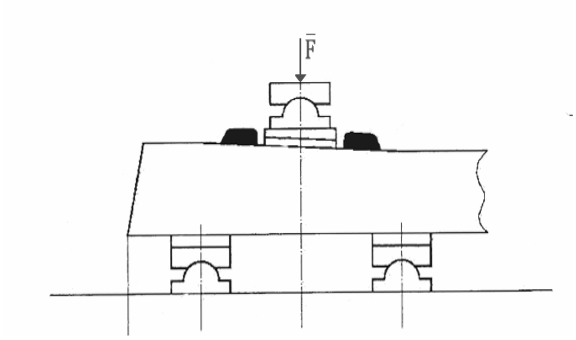

Fig.2. The Sleeper’s Loading Scheme.

Each of them is stretched with a force of 8,1 kN. Thus, the total load of sleeper’s ties after hardening concrete reaches to 356,4 kN. The main defects of concrete sleepers are: •

- Transverse cracks in rail pad position, •
- Fracture of the sleepers in the rail area •
- Transverse cracks in the middle of the sleeper •
- The break ties in the middle of the sleeper.
- Longitudinal cracks passing through the holes for bolts embedded
- Chips of concrete sleepers

Causes of these defects depend of manufacturing quality concrete sleepers, and are determined mainly operating loads.

3. The test procedure.

The work loads are completely reversed cyclic loading in the zones under the rail foot of the rolling wheel sets. Therefore, quality control technology of sleeper holds, using dynamic tests, in accordance with the scheme of loading single-span beam (Fig.2). In this case, the typical cycle amplitude loading is close to sinusoidal.

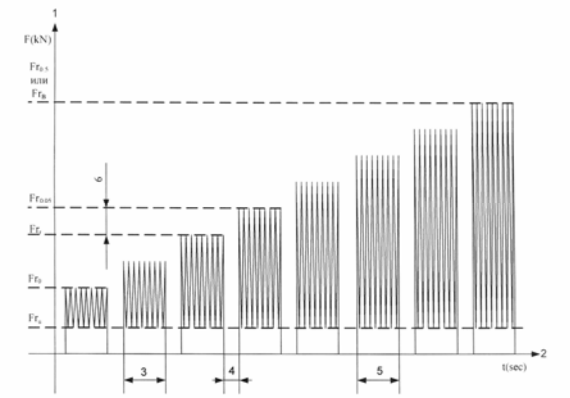

Fig.3. Schedule changes in the amplitude of loading dynamic tests

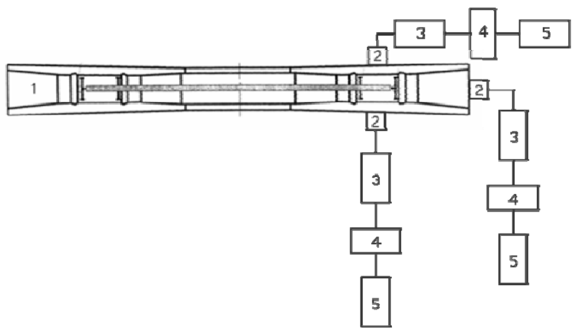

Fig.4. The location of the sensors on the sleepers IV. Legend: 1-sleeper, 2-AE-sensor, 3-Preamplifire, 4-AE unit, 5-Frequency unit (for sleepers 1,II,III – only one side position)

In the remaining steps to determine the maximum dynamic load at which the sleeper is destroyed, it is provided pursuant to [1] provides for the application of the dynamic load in steps to 20 KN, and, at each stage runs 5000 load cycles. After the step load is reduced to zero and visual inspection of the sleepers is made. At the same time consistently defined dynamic load, after removal of which the sleeper under the rail lining the crack width is 0,05 mm. Dynamic load, which corresponds to the limit of destruction or value, which persists after removal of a crack width of 0.05 mm, which is also considered to be the destruction of sleepers. Measure the width of the crack was carried out, usually at the end of the crack earlier stages of loading by means of Brinell microscope (magnification x24, scale division 0.05 mm).
It should be noted that visual inspection and measurement of the width of the crack must be made within a fixed period of time - no more than 5 minutes. The reason is that the action of forces, attracting sleepers who are in this case 350 kN, formed of the crack in the process of dynamic loading, and observed with the naked eye, these are compressive strength after removal of the cyclic loading for about 5 minutes is not time to pull off (close) bank fissure, and their can be measured during this time an instrumental method. After 5 minutes to detect such cracks can not because crack "cure". This effect was observed in almost all tested sleepers. Four sleepers have been checking. For convenience, we denote

them, respectively, sleepers № № 1,2,3,4. Methods of testing the three sleepers № № 1,2, 3 includes setting sensor on one of the sides in the middle of the sleepers in place of the minimum passing dynamic load, which is expected to begin demolition. AE sensor was attached to the surface of the sleepers with vibration glue type "TSIAKRIN. The fourth tie for the comparative evaluation of 3 sensors were attached, as shown in Figure 4. Sensors 1,3 fastened on the sides of the sleepers, Sensor 2 - at the end of one of the elements of the valve. As analyzing AE equipment used 3 appliance AF-15 with a bandwidth of (each) from 20KHz to 2 MHz. Monitors the total was selected by the AE, which recorded frequency meter H-3-36 from each device.

4. Test data

Destruction of sleepers № № 1,2,3 happened during the dynamic load of 250 ± 200 kN at the 18th stage (see Fig.6,7,8,9,) The destruction of sleepers number 4 occurred at the 14th stage with a load of 200 ± 150 kN. Visual inspection during routine inspections according to the standard [2] discovered the appearance of cracks with the disclosure of the crack on the value of 0,05 mm in the sleeper number 1 after the 8th stage of dynamic loading. At sleepers № № 2,3 - after a 15th, and the sleeper № 4 crack formation with a wide opening to the end of the fracture was not detected (revealed only the disclosure of 0,01 mm with a load of 170 ± 120 kN for the 10th stage). At Fig.5 as an example, shows a photograph of sleepers № 1, taken after the 17-th stage of loading and it's fracture.

A) B)

Fig.5. Kind of cracks on the lateral surfaces of the sleepers I after being subjected to 17th stage. A): current cracking, B) the sleepers fracture (it is AE gauge is seen on the side of the sleeper)

It is seen that on the right side of the sleepers in the upper part of the surface formed three independently developing cracks. On the left side surface formed a crack. These cracks were detected only when the sleeper was under dynamic load during the test. In the process of visual inspection with no load time to crack "heal" and as a consequence of residual reducing valves and effort they are not visually detected. Detection of cracks with no load began only after the branching (indicated nameplates - arrows with shading). The number on the label must (arrows) indicates the number of stages of dynamic loading. On the 18 th stage Sleepers destroyed.

At this stage the dominant is the appearance of a grid of cracks, chips and spalling concrete. The appearance of large cracks and separation into fragments occurs within a few cycles. Such behavior is typical for all tested sleepers. Therefore, a characteristic sign of close ties is the beginning of the destruction of branching cracks detected visually under a dynamic load of sleepers. Analysis of the total bill and the intensity of dynamic loading, shown in Figures 6,7,8,9 show an obvious relationship between the signals of AE and durability tested sleepers.

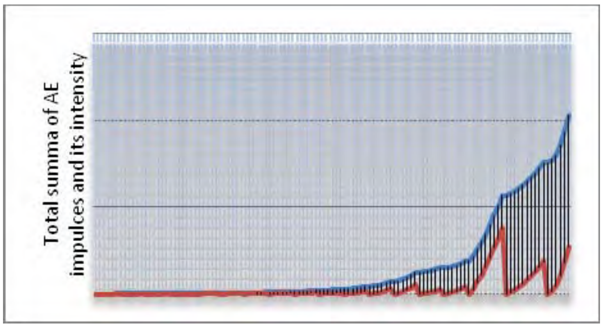

Fig.6. AE diagram for Sleepers N1 (blue line – total summa of AE impulces, red –AE impulces intensity)

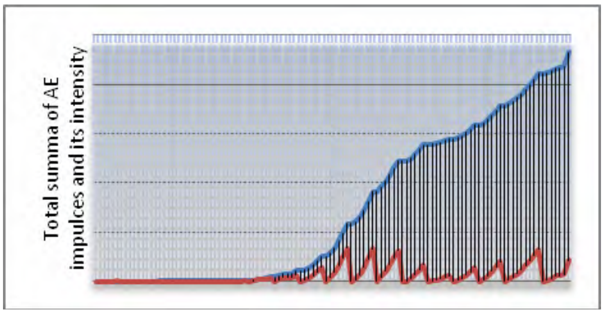

Fig.7. AE diagram for Sleepers N2

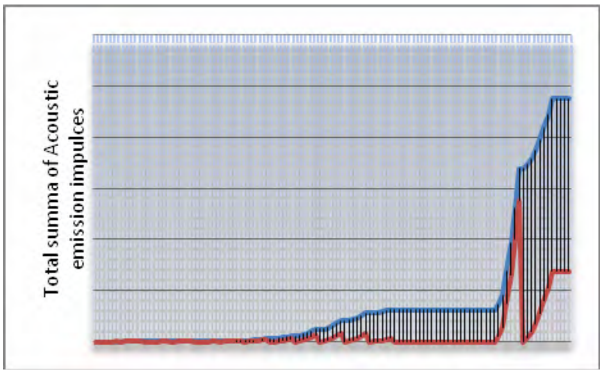

Fig.8. AE diagram for Sleepers N3

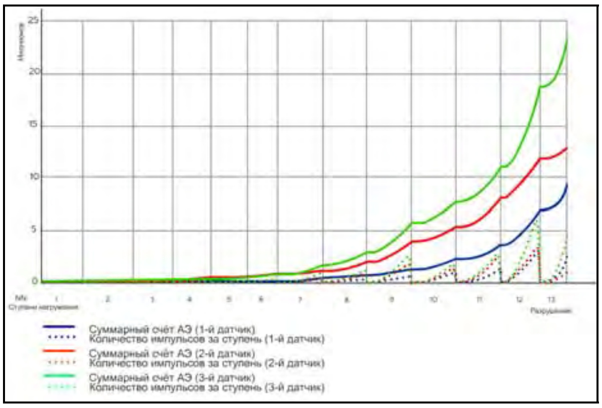

Fig.9 AE diagram for Sleepers N4(total summa and AE intensity- three AE sensors)

Thus, judging from the change in the intensity of AE signals, the first signs of cracks started at sleepers № 4 with 2nd loading stage, and she collapsed on the 14 th stage. Vitality was 12 degrees. Signs of cracks in sleepers began № 1,2,3, respectively, on 6th and 7th levels. They collapsed at the 18 th grade level. Vitality for these sleepers was respectively 12 and 11 degrees. Therefore, AE can act as a method to evaluate the quality of manufacturing sleepers: the latest recorded AE signals, the better sleeper. In addition, at the beginning of registration of AE signals can give a quantitative assessment of the survivability. In this connection, we can conclude that the quality sleepers № № 1,2,3 higher than the sleepers № 4, which collapsed without detection of a crack width of 0.05 mm according to the standard. It is worth noting one important feature of the behavior of the total AE in the process of dynamic loading from stage to stage (See Figure 6,7,8,9) - their identical behavior. Thus, each step of dynamic loading can be divided into 2 sections of the total behavior of AE (Fig. 10): plot slow (weak) growth and the plot fast (rapid) increase with the formation of the angle α.

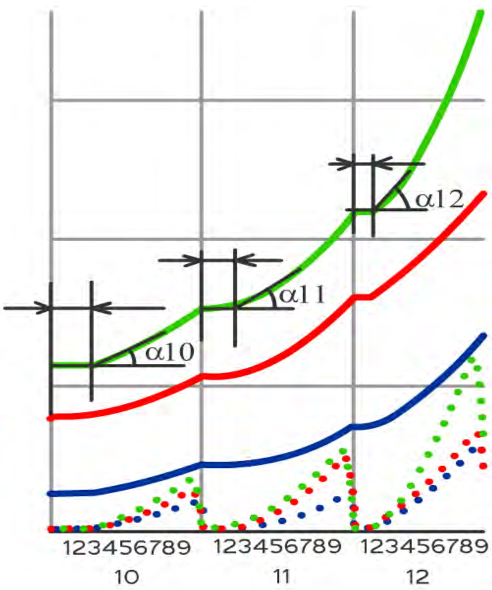

Fig.10.The fragment of AE diagram for Sleepers N4.

On the Fig.10. is shown of the changes of the total account of AE at 10, 11,12 stages of loading, this behavior can be explained by the following : in [2] it is shown that the formation of the angles α for metals associated with the moment of formation of microcracks, ie, associated with the destruction in the microvolume. The compressive strength has time to partially restore the structural integrity to the atomic level. Therefore, the beginning of each stage is accompanied by a small sum of AE, because yet there is no formation of new cracks. With further cyclic loading, damage accumulation is sufficient to initiate cracking and fracture of the material concrete. This leads to a rapid increase in the total AE and the formation of the angle α. Moreover, the number of loading cycles, which yields an angle α, tends to decrease from stage to stage. This phenomenon can be used in future for the development of the AE criterion for quantifying reducing the compressive force rods of any reinforced concrete structures.

4. Conclusions

During the stepwise loading test for preressed reinforced concrete sleepers, at the beginning of each loading stage on the graphs of the total number of acoustic emission impulses have been revealed “plateau “ (the absence of accumulation of pulses). This shows the effect of healing of cracks in concrete. This effect can be used as an additional criterion for testing the quality of adhesion reinforcement with concrete sleepers.

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