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# FIELD AND LABORATORY INVESTIGATION ON THE LATERAL RESISTANCE OF SLEEPERS BY EMPLOYING STPT TEST

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## Abstract

Welding rail joints in Curves with radius less than 400 meters is not applicable. Consequently, maintenance costs in many old railway tracks increases rapidly. Moreover, deterioration of track components, plastic deformation and critical cracks to the rail head, failures in sleepers, failure in fasteners, ballast bed damage and lateral movement of railway track occur besides of rail joints. There are many methods to increase the lateral resistance of the railway track such as changing the type of sleepers, changing sleeper intervals and employing new technologies. Since the lateral resistance of a standard mono block concrete sleeper in a ballast bed mainly consists of the frictional forces between the ballast stones and the sleeper bottom, this article will investigate the changes in lateral resistance of railway track by employing STPT test on frictional sleeper and comparing the results with standard sleeper.
An experiment has been directed on a track with and without frictional sleepers in SRE LAB-IUST and its result shows that the lateral resistance of the railway track increases approximately 59.1% by using frictional sleepers. In addition, a field investigation on an actual track with and without frictional sleepers has been directed to extend the results and it has been found that the lateral resistance of the railway track increases approximately 149% by employing frictional sleepers. According to the test results rail joints in curves with radius less than 400 meters can be welded by employing frictional sleepers.

*Keywords: Railway track lateral resistance, Lateral stability, Sleeper resistance, field test, Friction*

## 1 Introduction

Maintenance costs extraordinary in Curves with radius less than 400 meters in many old tracks since employing Continuous Welded Rails (CWR) are not applicable and rails have to be connected by fishplates instead of being welded. Researches and investigations show that deterioration of track components, plastic deformation and critical cracks to the rail head, failures in sleepers, failure in fasteners, ballast bed damage and lateral movement of railway track occur besides of the rail joints. Consequently, the lateral resistance of the railway track should increases in order to employing CWR in Curves with radius less than 400 meters. There are many methods to increase the lateral resistance of the railway track such as changing the type of sleepers, changing sleeper intervals and employing new technologies. Different studies have been directed so far to evaluate the lateral resistance of the railway track such as Kerr [8] and Nordal [2] and Lohren studies. This paper discusses the Field [3] and laboratory [4] investigations on lateral resistance of railway track with frictional sleeper, designed and constructed by the first author. Frictional forces between the ballast bed and the sleeper bottom have an important role in railway track lateral resistance; therefore, by employing STPT test on frictional sleeper and ordinary concrete sleeper, this article discusses the changes in lateral resistance of railway track.

## 2 Lateral resistance measuring methods

Lateral resistance is one of the most important factors for preventing track buckling. This resistance depends on the following factors:

- Sleeper type, weight and dimensions; rail and fasteners type and sleeper intervals
- Ballast gradation
- Ballast material quality
- Ballast depth in the crib and the shoulder height above the sleeper bottom
- Ballast compaction

The resistance to the lateral displacement can be measured by the following methods [1]:

- Single sleeper method or Single Tie Push Test method (STPT)
- Panel displacement method
- Mechanical track displacement method
- The method using a derailment wagon
- Continuous dynamic measurements of lateral resistance
- Lateral tensile test in the middle of the sleeper

### 2.1 Single sleeper method or Single Tie Push Test method (STPT)

In this method, the rail fasteners are removed and the sleeper is pushed against the rail with the help of a hydraulic device.

### 2.2 Panel displacement method

4–6cm long panels are displaced against foundation. These panels are pushed and their lateral movements are measured.

### 2.3 Mechanical track displacement method

In this method, additional equipments attach to the tamping machine and its track lining cylinder provides the lateral force. The lifting cylinder applies the vertical load and the displacement is measured by the lining value transducer [7].

### 2.4 The method using a derailment wagon

The measuring equipments attach to a real wagon. This method has the advantage that the stress in lateral direction comes closest to its actual value.

### 2.5 Continuous dynamic measurements of lateral resistance

Using this method has the advantage that lateral resistance can be measured continuously during a railway track [5], [6]. The measuring equipments attach to Dynamic Track Stabilizer (DTS) machine and measure the resistance to the lateral resistance during work. This machine measures the friction work involved and correlates it with resistance to lateral displacement, as shown in Eq. (1).

$$P_{supply} = P_P.V_P.f = F_v.\mu.A.f + P_{loss}\left[W\right] \tag{1}$$

Introduction of a standardizing reference vertical static load $F_N$ (Resistance to lateral displacement at a vertical load of 100 kN) produces the Eq. (2).

$$P_P.V_P.f.\frac{F_N}{F_V} = F_N.\mu.A.f + P_{loss}.\frac{F_N}{F_V} = QVW.A.f + P_{loss}.\frac{F_N}{F_V}[W] \quad (2)$$

The Term $\mu F_N$ shows the standardized frictional power, The Resistance to Lateral Displacement (RLD) with a vertical load of 100 kN. RLD is shown in Eq. (3).

$$RLD = \frac{P_P.V_P.f.\frac{F_N}{F_V} - P_{loss}\frac{F_N}{F_V}}{A.f}[N] \quad (3)$$

$P_P$ – Hydraulic working pressure of the drive motor of the vibrating unit (Pa)
$P_P$ – Pump filling volume of the hydraulic motor (m3)
F – vibration frequency (Hz)
$F_N$ – Standardized normal force (N)
$\eta$ – Efficiency of the hydraulic motor
$F_V$ – Vibration force acting on the stabilizing units
$A$ – vibration amplitude of the stabilization unit
$\mu$ – Coefficient of fiction between sleeper and ballast bed
$P_{loss}$ – Pressure loss of hydraulic device (W)

The resistance between a standard mono block concrete sleeper and the ballast bed mainly consists of three components: friction at the bottom, friction on the sides (crib zone) and passive pressure at the end of the sleeper (shoulders).
The friction coefficient between ballast stones and the sleeper bottom is measured 0.5, while the internal friction coefficient of crushed stone ballast is in the range of 0.9-1.4. Employing the frictional sleeper, recently designed and manufactured by the first author, increases the lateral resistance of the railway track by exploiting the more of internal friction potential of the ballast particles.

## 3 Design of the frictional sleeper

This kind of frictional sleeper is a new concrete sleeper with a course toothing surface at the bottom (Fig. 1). The lateral resistance of the railway track increases by employing frictional sleeper. The toothing bottom of the frictional sleeper exploits the high internal friction between the ballast particles and the bottom of the sleeper. In fact, ballast particles are forced up into the toothing by traffic load, tamping and vibrations where they hooked up and wedged between ridges leading to an effective fixation of the sleeper in the ballast bed. In other words, a continuous layer of ballast, held fixed to the sleeper bottom, causes the shear zone to pass underneath this layer where the shear interlocking and the internal friction of the ballast atones can be utilized to resist highly against the lateral movement of the sleeper [8].

**Figure 1** Frictional sleeper bottom

As shown in Fig. 2, the structure of this special type of frictional sleeper is like an special mono block concrete sleeper (B70) expect it's beneath surface. In fact, frictional sleeper has trapezoid shape toothing at the underside. This toothing surface increases the friction between ballast bed and the sleeper bottom.

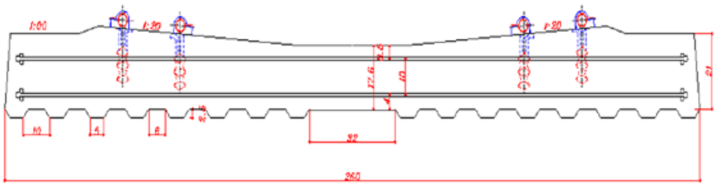

**Figure 2** Frictional sleeper

## 4 Laboratory Tests

Laboratory test were directed on a short section of a railway track with ten sleepers (Fig. 3). Track characteristics are shown as followings [4]:

- Cant: 0 (mm)
- Rail: UIC60
- Sleepers: concrete mono block (B70) and frictional sleepers
- Sleeper intervals: 600 (mm)
- Fastening system: Pandrol
- Ballast shoulder width: 35 (cm)
- Embankment slope: 2 to 3
- Depth of ballast in the crib zone: half
- Ballast gradation: good


**Figure 3** Sleepers in numerical order

Track lateral resistance was measured, first on the track with B70 mono block concrete sleepers. Then the B70 mono block concrete sleepers were replaced by the frictional sleeper and lateral resistance of the track was measured again. The experiment conditions remain the same during the tests. The lateral resistance of the railway track reaches its maximum value in the middle of the track. Consequently, the measuring device was attached to the forth sleeper (direct connection between hydraulic jack and the movement value measuring gage spring with rail web was not applicable on 5th sleeper because of existing of fish plates). Fig 4 compares the ordinary and frictional sleeper resistance and shows the curve fittings.

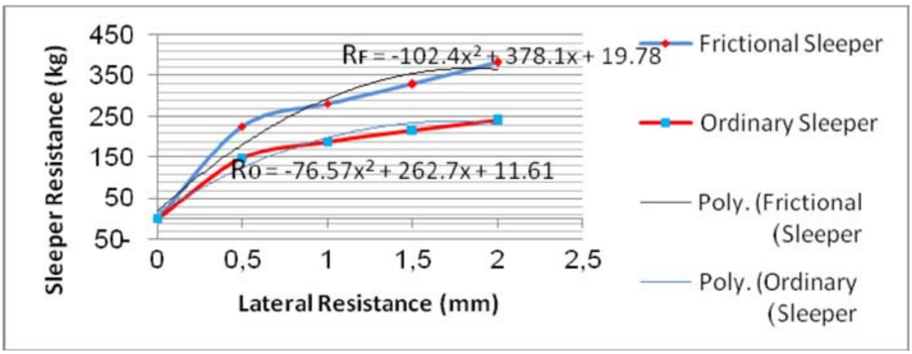


**Figure 4** Comparison of ordinary and frictional sleeper resistance curve fittings-Single sleeper laboratory test

The test results indicate that replacing ordinary sleepers by frictional sleepers increases the lateral resistance of the railway track by approximately 59%.

## 5 Single sleeper method under filed conditions

Single sleeper method involves pushing an unfastened sleeper laterally in the ballast bed. The rail fasteners are removed and the sleeper is pushed against the rail with the help of a hydraulic device. In this experimental investigation, the single sleeper method has been directed on the mono block concrete sleeper and frictional sleeper with the help of KS-625N, Sleeper holding test recorder. This machine consists of an electric pump, high pressure hose, hydraulic cylinder, display and record device and movement value measuring instrument. The hydraulic cylinder and movement measuring instrument are installed at the Pandrol fastening shoulder after taking out the fastening and sleeper pad. The pressure rises from hydraulic pump is to be sent to hydraulic cylinder terminal by the help of high pressure hose. The force required to move the sleeper and the distance the sleeper is displaced is measured on 0.5mm movement value. The hydraulic cylinder attaches to a frame that reacts against the fastener

shoulder on the test sleeper at the outer side of the rail and the movement value measuring instrument attaches to the pandrol shoulder at the inner side of the other rail. By pushing the sleeper laterally the rail begins to displace, consequently, the string of the movement value measuring instrument, compressed before loading, decompresses and the displacement of the sleeper can be measured [3].
The KS -625N is to measure the resistance force on sleeper movement value. Moreover, by setting the sleeper interval, ballast lateral resistance force can be calculated.

**Figure 5** Single sleeper test

### 5.1 Test results

#### 5.1.1 Single sleeper test on ordinary sleeper

In this step the sleeper resistance on the actual track was measured. The results indicate that sleeper resistance increases when the loading rate and lateral movement increase and becomes its maximum at the displacement of 2mm (Fig. 6)

#### 5.1.2 Single sleeper test on frictional sleeper

This experiment was directed on an actual track with frictional sleeper with the same conditions as the former test. The sleeper resistance was measured as shown in Fig. 6.Test results indicated that the sleeper resistance became its maximum at the displacement of 0.9mm.

### 5.2 Assessment the single sleeper test results

In this section, the ordinary and frictional sleeper test results are compared in Fig. 6. Furthermore, by Comparison of ordinary and frictional sleeper resistance curve fittings, shown in Fig. 6, the relation between sleeper resistance and the lateral movement comes as Eqs. (2) & (3):

$$R_f = -0.827x^2 + 2353x + 2E - 3 \quad (4)$$

$$R_o = -229.4x^2 + 821.4x + 95.28 \quad (5)$$

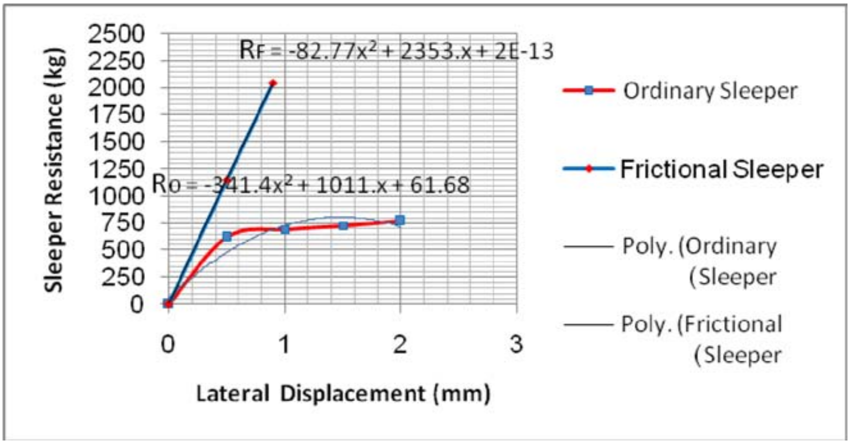


**Figure 6** Comparison of ordinary and frictional sleeper resistance curve fittings- Single sleeper under field conditions

Field test results indicate that the frictional sleeper lateral resistance is approximately 2.46 times as ordinary sleeper lateral resistance.
According to section 4 and section 5 test results, employing frictional sleeper effects on the incensement of railway track lateral resistance can be considered. However, the different between laboratory and field test results can be explained as followings:

- In the laboratory tests, no vertical load was applied on the test track. Applying vertical load; however increases the ballast compaction on the actual track.
- The ballast layer depth was approximately 20cm in the laboratory tests and the ballast shoulder width was considerably less than the actual track.
- Repeating test caused the shear interlocking between ballast stones to reduce in the laboratory tests.

## 6 Conclusion

The lateral stability of the railway track depends on the lateral resistance of the sleepers, ballast bed and fastening systems. Omitting and welding rail joints cause huge longitudinal forces in the rails leading to the rail buckling. Consequently, professionals have suggested different method to increase railway track lateral resistance. This study introduces a new frictional sleeper with a course toothing surface at the bottom. Employing this frictional sleeper increases the railway track lateral resistance by exploiting high internal friction potential of ballast stones. In this study, laboratory tests were directed on the frictional sleeper and it was found that by employing frictional sleepers instead of ordinary sleepers, lateral resistance increased approximately by 59.1%. Field test, also were directed to extend the result; in this case, the sleeper lateral resistance increased approximately by 149%. In conclusion, by replacing ordinary sleepers with frictional sleepers, the rail joints can be safely welded in curves with radius less than 400m.

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