Special edition paper

Optimization of Structure of “Next-Generation Turnouts”



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Abstract

To reduce transport disorders from switch failures and reduce labor for maintenance, next-generation turnouts (2000-type) were introduced in the greater Tokyo area starting in fiscal 2002. To expand the area where the next-generation turnouts are installed, we optimized the structure of the next-generation turnout and conducted endurance tests. As a result of this, the new structure of the next generation turnout has been shown to have sufficient endurance and we can reduce the material cost about 20%.

●***Keywords*:** Next-generation turnout, Slide base plate, Grid type sleeper, Reduction of material cost

1. Introduction

JR East developed the “next-generation turnout” with aims such as reducing transport disorders due to turnout failure, reducing maintenance costs, and reducing the number of items to be inspected. Since fiscal 2002, more than 300 sets of that turnout have been installed mainly in the greater Tokyo area.[1) 2)] The next-generation turnout is an innovative type achieved by revising the overall functions of previous turnouts. Introduction of the next-generation turnout has demonstrated many functional advantages, making it a type of turnout for which expanded deployment is desirable. As part of that expansion, we have worked to optimize its structure and reduce its material costs. In optimization, we focused our studies on sleepers and base plate/rail fastening structures, which make up 70% of the material costs of the next-generation turnout. This paper will cover what we have studied up to now.

2. Study on Optimization to Expand Deployment

2.1 Review of Sleeper Structure

Fig. 1 shows the previous next-generation turnout (2000-type). Grid type sleepers (“slim grid type sleeper”) adopted for the 2000-type with which the track maintenance period has been extended by improving rigidity of track panels (seven times more rigid in lateral direction, two to three times more rigid in longitudinal direction than conventional turnouts) were streamlined while following conventional structure. Specifically, items we studied included extending intervals between rail fastenings, reducing the number of cross sleepers, downsizing the widths of short and cross sleepers, using thinner steel plates, and modifying welding specifications. Table 1 shows a comparison between conventional and slim grid type sleepers.

With streamlining, we should be able to reduce material costs by 20% compared with grid type sleepers of the previous structure.[3)]

Fig. 1 Next-generation Turnout (2000-Type)

Table 1 Comparison of Slim Grid Sleeper and Conventional Structure

	Conventical structure grid sleeper	Slim grid sleeper
Placement interval (interval between rail fastenings)	750 mm	900 mm
No. of cross sleepers	6	4
Cross sleeper width	300 mm	250 mm
Short sleeper width	350 mm	250 mm
Steel thickness	12 mm	9 mm
Welding specs	Fillet weld thickness of 12 mm on perimeter of joint of longitudinal and lateral members	Fillet weld thickness of 9 mm on perimeter of joint of longitudinal and lateral members

2.2 Review of Base Plate/Rail Fastening Structure

Some clips and risers of raised base plates adopted with the fastening structure of the 2000-type are procured overseas, presenting the issue of high material costs. We thus studied under the concept of domestic procurement of fastening materials monoblock casting of raised base plates and new structure for fastening the rail on both sides in which flat springs and wedges are combined. Fig. 2 shows a comparison of the 2000-type plate/rail fastening structure and the newly developed next-generation turnout.

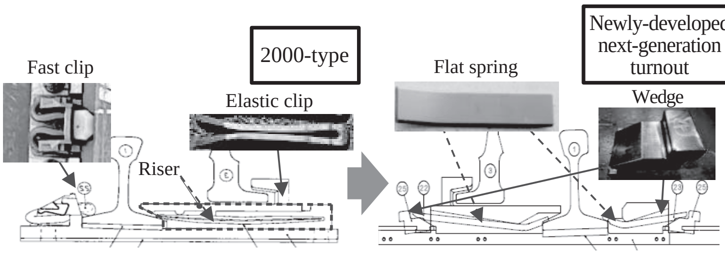

Fig. 2 Comparison of Current and Previous Base Plate and Fastener

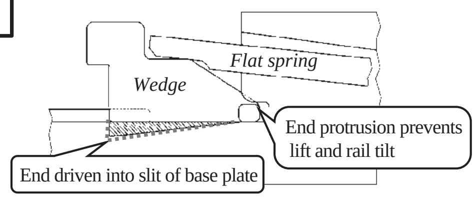

Fig. 3 Fastening Mechanism of Newly-developed Next-generation Turnout

A structure was adopted where wedges are driven at the edges of flat springs to raise them and apply reactive force as the fastening force. The mechanism for this is the ends of the wedges being driven into groves on the base plates and secured, resisting lateral force. Protrusions on the end fitting into cutouts on the base plates fulfil a role of preventing wedge lift and rail tilting (Fig. 3).

By domestically procuring fastening materials and reviewing the production process for base plates, we should be able to reduce material costs by 30% with the newly developed next-generation turnout while maintaining fastening force equivalent to that of the fastening structure of the 2000-type.

3. Point Part Prototype Construction and Performance Confirmation Tests

3.1 Point Part Prototype Construction and Performance Confirmation Tests

We combined the aforementioned slim grid sleeper and base plate/rail fastening structure, produced a prototype point part for the next-generation turnout for #12 60 kg rails, and preformed performance tests on our full-scale fatigue testing machine. The following covers the details of that.

(1) Static loading tests

Static loading tests were performed under the two conditions of simultaneously applying wheel load and lateral force and applying wheel load only. Fig. 4 shows load and load position under both conditions and Table 2 shows the items measured. The maximum load here is set to be the A load (exceptionally large load that occurs in extremely rare instances). Table 3 shows the stress generated and irregularity of materials under both conditions. From the test results, we were able to confirm that stress generated at the grid sleeper and rail base and rail tilt were less than permissible values[5] under both conditions and impact on locking is small.

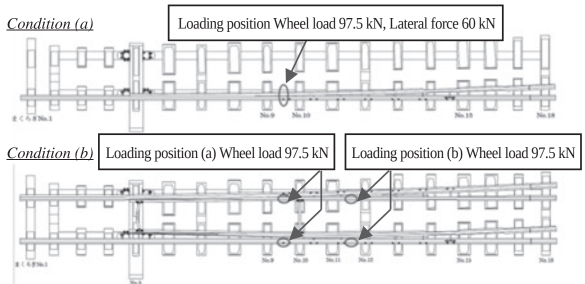

Fig. 4 Loading Position and Load at Each Condition

Table 2 Measurement Items List

Item measured	Measurement item
Grid sleeper	Bottom stress
	Weld stress
	Sleeper bottom stress
Rail	Base stress
	Rail tilt
	Flex between sleepers
Overall	Track subsidence
Impact on locking	Stock rail lateral irregularity
	Tongue rail lateral irregularity

Table 3 Static Loading Test Results

	Measurement item	Permissible value	Max. value (condition 1)	Max. value (condition 2)
Grid sleeper	Bottom stress	190 MPa	13.6 MPa	10.5 MPa (loading position (a))
	Weld stress	190 MPa	95.4 MPa	56.3 MPa (loading position (b))
Rail	Base stress	196 MPa	37.1 MPa (Stock rail)	Stock rai: l59.1 MPa (loading position (a)) Tongue rail: 65.7 MPa (loading position (a))
	Rail tilt	7 mm	1.41 mm	0.59 mm (loading position (b))
Impact on locking	Lock irregularity	1.5 mm	0.09 mm	0.09 mm (loading position (a))

(2) Dynamic loading tests

At loading position (a) where stress generated on grid sleepers is maximum in condition (b) of static loading tests, we continuously applied cyclic load of 100 kN maximum and 5 kN minimum at 7 Hz frequency. This was done to a cumulative 20 million tons, the target annual passing tons for the greater Tokyo area, and we measured stress generated on the material. No great fluctuation in stress generated on the material was seen, and no fasteners fell off or were damaged.

3.2 Switching Tests for Newly Developed Next-generation Turnout

Compared with the 2000-type due, the prototype turnout produced this time has a different point part plate/rail fastening structure and base plate position as well as a different bearing base plate position due to increased interval between base and grid sleepers. We thus installed a point machine (ES-II) to the prototype and confirmed switching performance. In switching performance confirmation, we compared changes in switching torque occurring at the ES-II when switching the tongue rail with torque generated when switching with the 2000-type. We performed continuous switching to a target of about 100,000 times and confirmed contact/adhesion of tongue rail and stock rail and that no damage or wear occurred at the base plate surface on which the tongue rail slides. Fig. 5 shows comparisons in change in switching torque. The prototype demonstrated similar change in torque to that of the 2000-type, and we confirmed that maximum torque generated is within the rated output range of the ES-II. Moreover, functional and material abnormalities were not found in continuous switching tests as well. From this, we confirmed that the newly developed next-generation turnout has similar switching performance to the 2000-type.

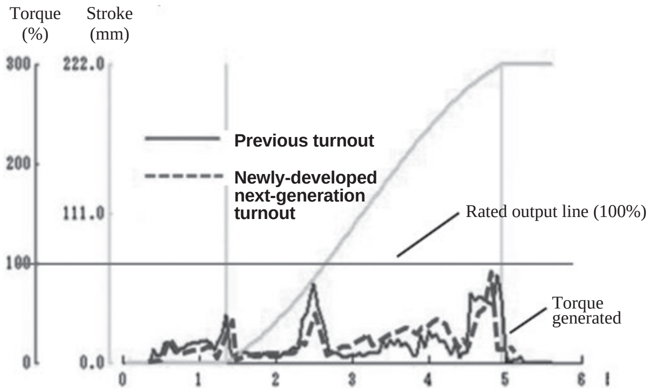

Fig. 5 Comparison of Changes in Torque Generated at ES-II

4. Installation on Commercial Lines and Performance Evolution

4.1 Installation on Commercial Lines

In order to evaluate performance of the newly developed turnout under commercial line conditions, we installed the prototype in the yard of Odawara Station on the Tokaido Line on November 20, 2017. Table 4 shows a profile of the turnout and Fig. 6 shows it installed.

Table 4 Turnout Profile

Station	Turnout number	Type	No times switched (times/year)"	Annual passing tons (million tons)"	Passing direction
Odawara	58A	60 k simple turnout 12#	32,120	22.9	Facing

Fig. 6 Installed Turnout

4.2 Performance Evolution

We measured rail irregularity and stress on the sleeper as well as track subsidence at the turnout when trains passed the turnout in order to evaluate performance. Table 5 shows rail and grid sleeper measurement items and Fig. 7 shows measurement locations for track subsidence.

Table 5 Measurement Items List

Rail		Grid sleeper	
Measurement item	Measurement point	Measurement item	Measurement point
Wheel load	3	Grid sleeper stress	8
Lateral force	4	Track bed vibration	4
Rail vertical irregularity	2	Grid sleeper vertical irregularity	6
Rail horizontal irregularity	2	Synthetic sleeper stress	1
Rail base stress	3		

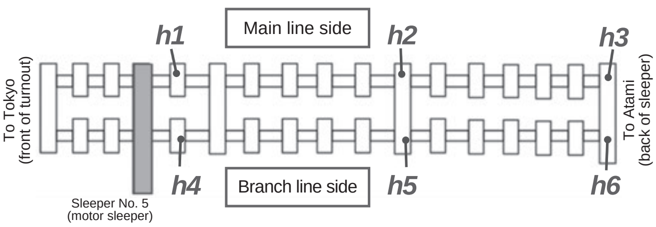

Fig. 7 Track Bed Subsidence Measurement Positions

4.3 Evaluation Results

(1) Track subsidence measurement

Track subsidence was measured in terms of subsidence of each sleeper shown in Fig. 7 (h1 to h6) continuously for two months after installation. Fig. 8 shows the measurement results. The newly developed next-generation too shows general subsidence tendencies of turnouts, and exceptional subsidence was not recognized. The greatest subsidence was seen at h1 on the main line side at 7.1 mm, and subsidence at main line side sleepers (h1 to h3) was greater than at branch line sleepers (h4 to h6) by approx. 1.5 to 2 times. This is thought to be due to loads received by main line sleepers from trains having greater impact due to orientation of the turnout.

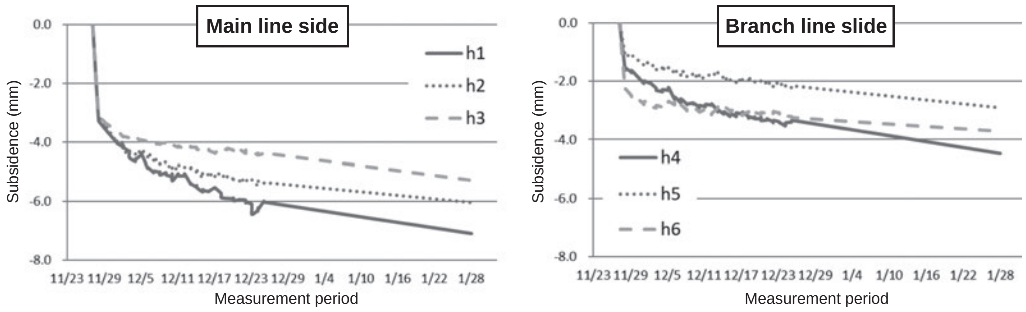

Fig. 8 Track Subsidence Measurement Results (left: main line side, right: branch line side)

(2) Stress and Irregularity Measurement when Trains Pass

Items shown in Table 6 were measured when trains pass. Measurements were made for 10 passes of trains each for main line and branch line. Maximum values at measurement are shown in Table 6. Performance evaluation was done by comparing maximum values for each measurement item with running safety standards[4] and base material permissible stress.[5] From Table 6, we can see that wheel load and lateral force as well as irregularity generated at rails and sleepers are below running safety standards, and stress occurring at rails and sleepers are below base material permissible stress.

Table 6 Commercial Line Measurement Results (max values extracted)

Measurement item	Running stability standard and permissible value	Max. value (passing on main line)	Max. value (passing on branch line)
Wheel load	300 kN	63.1 kN	67.1 kN
Lateral force	68 kN	13.0 kN	17.1 kN
Rail vertical irregularity	4.0 mm	1.2 mm	1.0 mm
Rail horizontal irregularity	2.0 mm	0.5 mm	1.0 mm
Rail base stress	196 MPa	31.6 MPa	59.8 MPa
Grid sleeper stress	190 MPa	60.1 MPa	97.7 MPa
Track bed vibration	-	125 dB	125 dB
Grid sleeper vertical irregularity	3.0 mm	1.3 mm	1.8 mm
Synthetic sleeper stress	70 MPa	0.3 MPa	1.0 MPa

5. Conclusion

We worked to revise and optimize the structure of the 2000-type turnouts while maintaining its basic performance. By domestic procurement of fastening materials and streamlining grid sleepers, we should be able to reduce material costs at introduction by about 20% compared with the 2000-type. Moreover, we confirmed through tests by the newly developed next-generation turnout that there are no problems in terms of turnout material durability and switching performance, enabling us to install one on a line in commercial operation. We further measured material stress, irregularity, and the like under commercial line conditions, confirming that there are no problems in terms of durability.

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