SURVEYS OF GEOMETRY OF RAIL TRACK FACILITIES AND RAILWAY TRACKS IN THE INFRASTRUCTURE OF RAIL TRANSPORT

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1. INTRODUCTION

Transportation of people and freight is carried out with the use of railways, roads, airways and waterways. Polish and European railway carriers can compete with other modes of transport only if technical and construction norms of railways are standardized. Currently the European market for rail transport covers diverse technical and operational standards. These include among others: technical solutions of overhead line, permissible curve radii limits, types of rail track facilities, platform heights, clearance. A variety of the existing systems and related regulations is a serious barrier in an attempt to make technical standards uniform across Europe. Similar problems also occur in the Polish technical standards related to railway infrastructure. Despite the consistency of the current technical standards in regulations and norms regarding surveys of the geometry of rail track facilities, there are inconsistencies in the field of surveying, diagnostics, and even mapping. Rail track facilities, such as turnouts and crossovers are among the most sensitive places in the railway tracks. They may result in reducing the speed of trains running via through stations. Also they significantly inhibit motion works on holding tracks and marshalling yards. Increasing rail infrastructure decapitalization leads to a decrease in the level of transportation safety and rail capacity.

The article presents the subject of the surveys of geometry of rail track facilities and railway tracks. Evaluation of the surveyed objects along with an analysis of the results allow to take appropriate remedial steps before a worrying phenomenon or exceeding a given parameter becomes dangerous to human life and health, which will result in safety hazard in rail transportation. The surveys of the geometry of rail track facilities and railway tracks have been carried out on a double track railway line no.8 Warszawa Zachodnia – Kraków Główny Osobowy at 289,850.00 - 291,850.00 km (Fig. 1). They included the turnout head at Słomniki station in the area of dispatching switch tower

and the essential main tracks 1 and 2. The surveys of the geometry of rail track facilities implemented within the framework of technical research of the turnouts included (Fig. 3):

1. **two ordinary turnouts, no.17 and 18, of type Rz/60E1/190/1: 9, the no.17 turnout is built in the track no.2 and the turnout no.18 in track no.1,**
2. **two railroad double turnouts, the so-called scissors crossovers no.15 and 16 of Rkpd/60E1/R190/1:9 type, the no.15 turnout is built in the track no.2, while the turnout no.16 in the track no.1,**
3. **crossover of the tracks.**

Due to limitations in size, the article recognizes only the most important aspects for the inventory and operational surveys of rail track facilities and railway tracks, as well as for the measuring device RTE 2 (Fig. 2). Also the results of authors' surveys of railroad double turnout, the so-called scissors crossover no. 15 were presented.

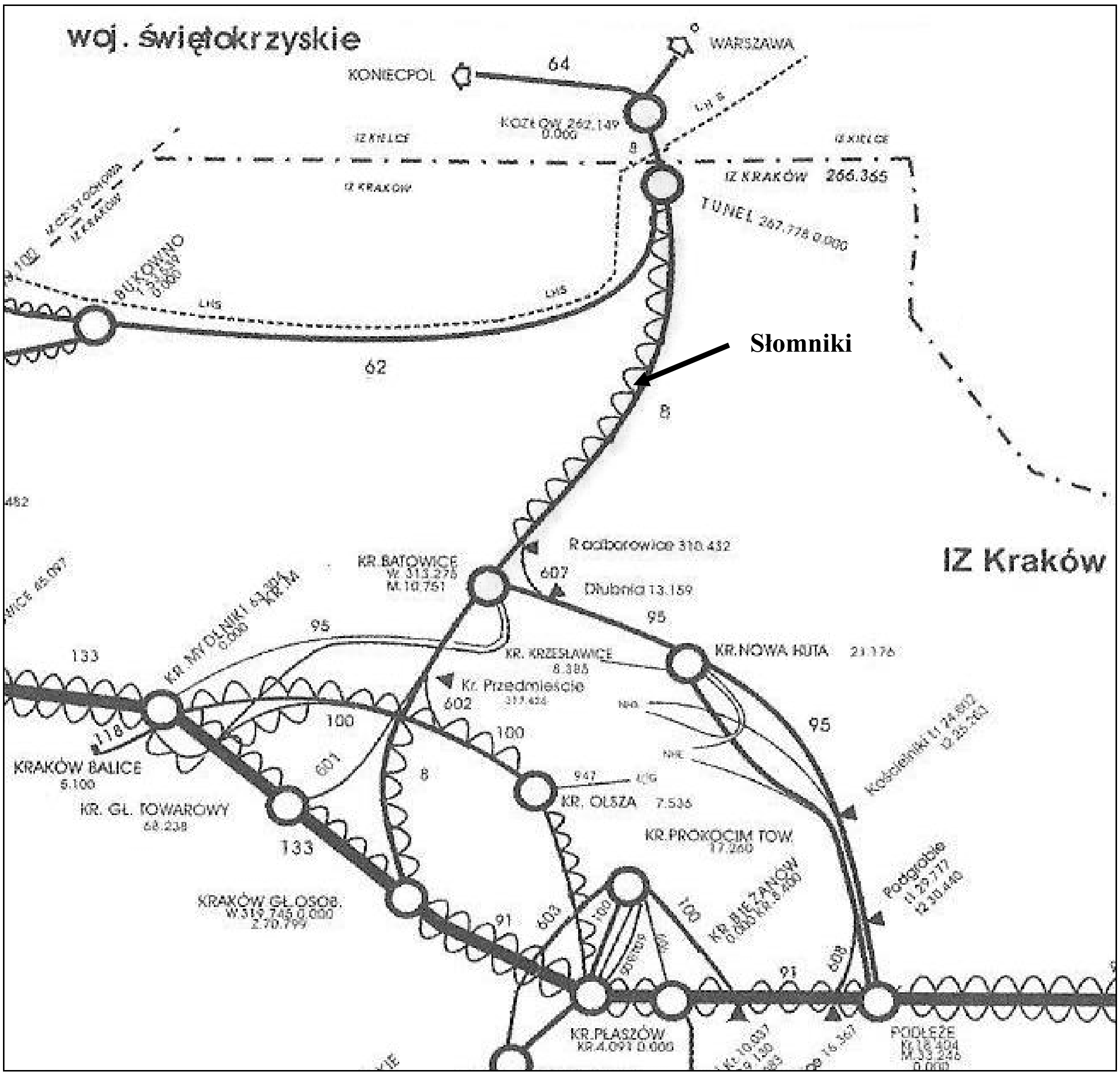


Fig. 1. Fragment of the schematic plan of the location of railway lines managed by the Department of Railways in Kraków.

2. TOLERANCES FOR THE BASIC PARAMETERS OF THE TRACK POSITION

In order to perform surveying and diagnostic measurements, an electronic self-recording track gauge RTE 2 PROVENTUS was used, thereby generating digital Sheets for Technical Research of Turnouts (cABTR). In the years 2006 to 2009 the analyzed line was modernized in terms of: superstructure, engineering structures, railway crossings, overhead line and construction of railway traffic control devices. On this line the maximum train speed was increased from V_R 50/60/70/80 km/h to V_R = 110 km/h. Railway line no.8, connects agglomerations of Radom, Skarżysko Kamienna and Kielce with Warszawa and Kraków. This is the line of a passenger and freight character, fully electrified, adjusted to the maximum train speed of 100-120 km/h. The introduced V_R = 110 km/h entails benefits due to the convenience and speed of travel. However, with the speed so defined, there is a problem in the analysis and assessment of the track condition. In the study of the tracks, which is carried out manually with the use of portable measuring equipment, the following items become subject to analysis (defined in millimeters):

- **the difference in arrows on the chord of 10 m,**
- **differences in horizontal distance from the reference points (so-called offset)**
- **the difference in heights between the grade-line and reference points,**
- **differences in the heights of the rail course position,**
- **differences in the nominal track gauge.**

Acceptable values of tolerances for the track position basic parameters for manual surveys have been summarized in "Technical Conditions Id-1 (D-1)". They refer to the so-called. even speed, for example: 80/100/120/140 km/h, etc. Currently, the applicable regulations and binding branch instructions do not have developed acceptable tolerances for such speed as 90/110/130/150 km/h. Further guidance relating to geodetic and diagnostic surveys of the tracks can be found in the Instruction Id-14 (D-75). Instruction provisions require that within the scope of the surveys (manual) conducted with the direct method, the following works should be performed:

1. **measurement of basic parameters characterizing the position of rail courses, i.e.:**
   - **track gauge,**
   - **differences in heights of rail courses,**
   - **irregularity of rail courses in horizontal and vertical planes,**
2. **measurement of additional parameters in the two planes, including:**
   - **location of the track in horizontal and vertical planes in relation to the track axis reference points,**
   - **value of play in the classic track contacts.**

Also in this case a problem arises during the analysis and assessment of the track. For the analyzed speed V_R = 110 km/h, with regard to the manual surveys, the values of acceptable tolerances for the basic parameters of the track position have not been determined.

Instruction Id-14 (D-75) also defines the elements of the geometry of the track, which are subject to observations using track measurement trolleys (track inspection cars, track geometry self-recording trolleys). These include:

1. **in the horizontal plane:**
   - **track gauge,**
   - **track gauge gradient,**
   - **irregularity of rail courses in the horizontal plane,**

2. in the vertical plane:

- **location of the track in cross section,**
- **track twist,**
- **irregularity of rail course in the vertical plane (track vertical irregularities) for the left and right rail course.**

Instruction Id-14 (D-75) contains the acceptable values of tolerances for the above-mentioned track position parameters for V_R = 110 km/h. Unfortunately, another problem arises, which is associated with the adopted maximum train speed. It concerns the proper interpretation of the position of the track axis and turnouts in the plan and profile in relation to the design values, with surveys carried out with respect to the reference points. Due to the fact that for the speed V_R = 110 km/h the instruction does not specify permissible tolerances, an analysis should be carried out for the closest speed, i.e. V_R = 100 km/h or V_R = 120 km/h. Permissible tolerance in the horizontal plane from the design value for the speed of V_R = 120 km/h equals 10 mm, while for the speed of V_R = 100 km/h it equals 15 mm. The person conducting the surveys and employees of diagnostic and surveying teams bear the responsibility for adopting appropriate tolerances and subsequent decisions taken in this respect.

Instruction Id-14 (D-75) also recommends measurements of the arrows in curves based on the chord with the length of 10 m. For the chords with the length of 10 m tolerances for differences of arrows were established. Unfortunately, the instruction does not provide for the differences of the arrows for the speed V_R = 110 km/h.

Support for works realization on the track poses a crucial problem as well. After each of the completed stages post-completion surveys are carried out. An investor conducting major repairs, modernization or current repairs also carries out acceptance surveys. During the inspection of individual geometric parameters, special attention is paid to retaining the assumed values. Unfortunately, there is no possibility to review various geometrical parameters for the"odd" speeds, namely: 70/90/110/130/150 km/h.

3. SURVEYS OF THE GEOMETRY OF RAIL TRACK FACILITIES

Properly conducted inventory surveys of the geometry of a turnout, crossover, wagon retarder, etc. allow to perform a proper analysis and assessment of the track condition. The results of the analysis enable to take appropriate remedial measures before an alarming phenomenon or exceeding a given parameter of the geometry of the rail track facility becomes a threat in rail transportation (Kampczyk, 2009). Diagnostics of rail track facilities include: turnouts, track crossovers, brake skids launchers, frogs at turntables and railway expansion joints (Kampczyk, Preweda, Sołtys, 2007). The scope of the diagnostic works mainly includes:

- **visual inspection,**
- **technical examination (inspections),**
- **special examination, whose scope is determined individually,**
- **analysis and evaluation of the results.**

The scope and methods of the surveys, performance tolerances, and documentation of diagnostic tests of turnouts are regulated by Instruction Id-4 (D-6). It is used in railway enterprises and industrial plants, which have rail sidings, holding tracks, cargo handling tracks, etc. In accordance with the requirements of the Instruction Id-4 (D-6) the study of these objects include:

- **checking the technical condition of all the construction parts,**

- **verification of the geometric system,**
- **operation and maintenance assessment of the condition,**
- **survey of the turnout geometry with respect to the track gauge, track cant, grooves, and other parameters indicated in the sheets for technical examination of turnouts (turnout specification).**

A commonly used surveying device that allows the direct determination of the parameter values characteristic for track turnout geometry is universal track measurement gauge. This instrument is used for manual surveys and direct readout of a clearance and cant, as well as other parameters characteristic of turnouts. Automation of surveying systems tends to continuous monitoring of track and turnouts geometry. This is made possible by the introduction of electronic surveying systems, allowing for increased accuracy and efficiency of measurements (Kampczyk, 2009). Electronic systems allow to create surveying databases for the turnouts and inserts between the turnouts. They make it possible to conduct specialized analysis and diagnostic assessment (Kampczyk, 2009). In recent years in Poland two types of electronic track geometry self-recording trolleys have been implemented. The first one is the Electronic Manual Track Gauge RTE 2 produced by PROVENTUS company from Katowice (Fig. 2). Another is Digital Track Gauge DTG produced by GRAW company - Laser Surveying Systems from Gliwice. This type of trolleys and accompanying professional expert software allow setting up digital Sheets for Technical Research of Turnouts (cABTR). Digital Sheets for Technical Research of Turnouts have been established for the purposes of the described examinations for the turnouts and crossover in Słomniki station.

Fig. 2. Surveying the geometry of turnouts and crossover in Słomniki station with a self-recording track measurement gauge RTE2 PROVENTUS.

Figure 4 shows the results of the authors' surveys with the digital Sheets for Technical Research of Turnouts applied for the railroad double turnout, the so-called scissors crossover no. 15 of Rkpd/60E1/R190/1:9 type. This crossover is built in the track no. 2 of the line no. 8 at Słomniki station. The surveys were carried out on 8th September 2010 using the self-recording track gauge RTE 2 PROVENTUS, equipped with professional applications. Thanks to these applications, data was transmitted to the PC and digital Sheets for Technical Research of Turnouts (cABTR) were generated. In these electronic forms it is possible to select appropriate and permissible tolerances for a particular turnout or crossover. The application automatically highlights in red the exceeded, with reference to the standards, values of the parameters measured in characteristic points.

Digital sheet for technical research of turnout no.15 consists of five main parts:

1. **heading, setting out the station name, number and type of the turnout, the date of installation, the manufacturer of the turnout, etc.,**
2. **turnout scheme with the marked characteristic points of the turnout at which the geometry surveys were conducted in the horizontal and vertical planes,**
3. **proper dimensions and tolerances for the track gauge parameter and cant, specified in [mm],**
4. **dimensions of the examined parameters,**
5. **date of the survey, an identity card of the person conducting the survey and examination, and his/her name and surname.**

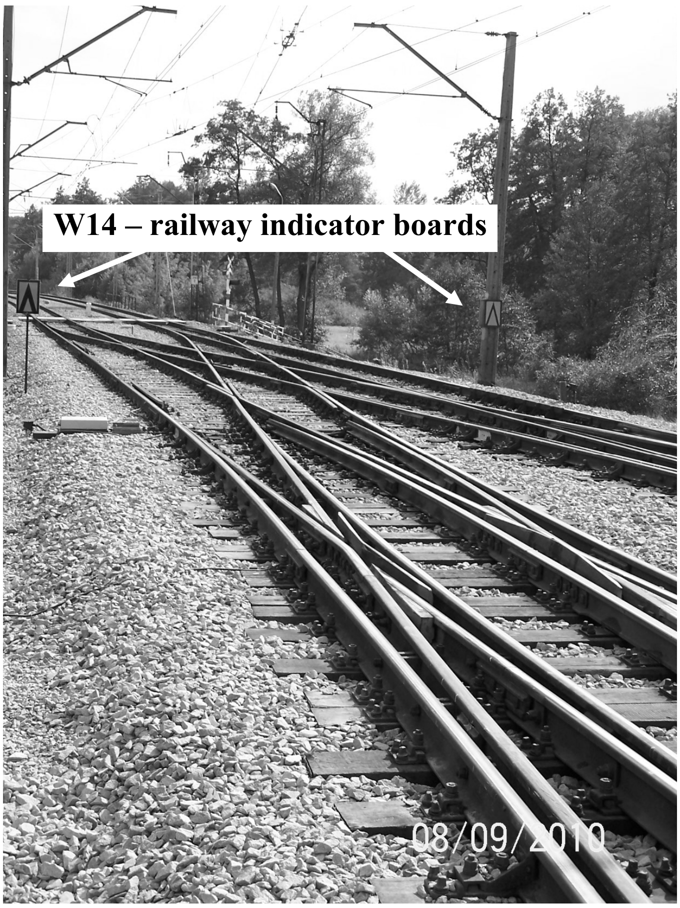


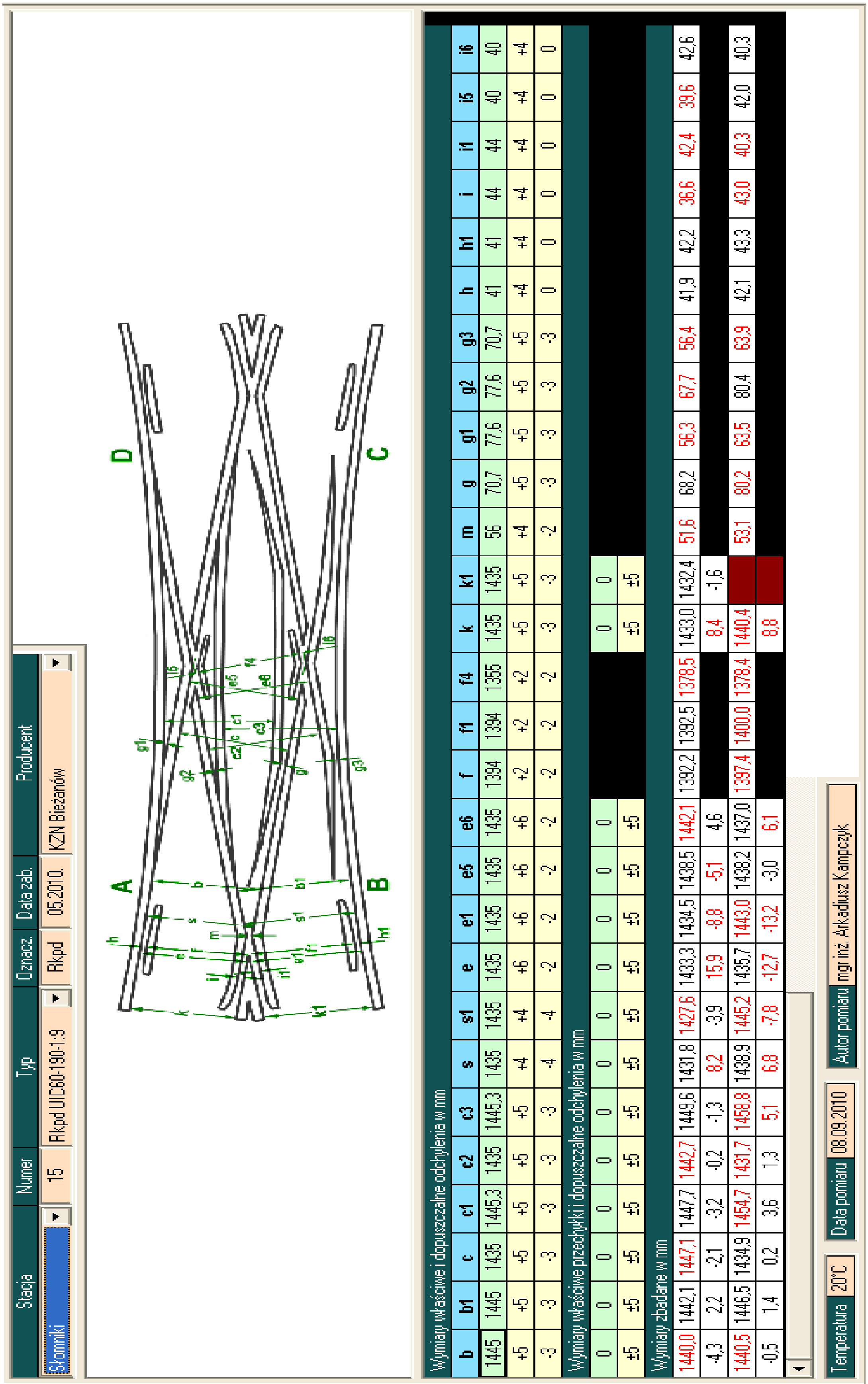
Fig. 3. Turnout head at Słomniki station, with the visible scissors crossover and W14 – railway indicator boards defining the beginning or the end of the section which must be covered at limited speed.

Unfortunately, digital sheets for technical research of turnouts are currently no longer applied. The reasons lie in the provisions of the Instruction Id-4 (D-6), which does not allow for the conduct of such electronic documentation. In practice, this means a significant reduction in the quick, automated and convenient use of modern technology. Thus there is an urgent need to modernize the records of this Instruction (Kampczyk, 2009).
In two of the railroad double turnouts of Rkpd/60E1/R190/1:9 type with numbers 15 and 16, despite an increase of the V_R speed at the no.8 line up to110 km/h, there is a speed limit Vo = 100 km/h (Fig. 3). This limitation is justified due to the existing regulations and construction standards which are binding for such turnouts. In accordance with the requirements specified in the Regulation of Minister of Transport and Maritime Economy (Dz.U. 1998 nr 151 poz. 987), scissors crossovers should not be applied in the tracks where the train speed in a straight direction is greater than 100 km/h. In addition, attention should be paid to the requirements of the Instruction Id-4 (D-6). It sets out the conditions of a rolling stock with different wheel diameters running through the scissors crossovers. When running through the scissors crossovers and through track crossovers with the frog angle of 1:9, a rolling stock with a wheel diameter of 840 mm is allowed to travel with the maximum speed limit of 100 km/h. And just such a frog angle is characteristic for the scissors crossovers and track crossovers at Słomniki station.

The acceptable values of tolerances for the basic parameters of the track position ensuring the ease of travel are dependent upon the speed. For the rail track facilities such as turnouts, crossovers, etc. the nature and type of the turnout are essential.

4. CONCLUSIONS

The presented study approaches the specificity of the work of professionals responsible for the surveying and diagnostic descriptions of elements of the rail surface. However, the focus was on the description and analysis of selected types of railway turnouts, built in a modernized track. Each specialist involved both in handling investments in railway areas in terms of surveys, as well as rail surface diagnosis, should have an expanded and extensive knowledge of surveying and railway legislation. However, it was proved in this paper that even substantive evidence of good preparation to perform the described work, sometimes does not protect against the difficulties in unambiguous assessment of the track. Therefore, extensive legislative works aiming to unify and modernize the regulations are needed urgently. This is related both to discrepancies in the provisions contained in various manuals and guidelines, as well as to more and more pervasive computer technology in various industries. Both specialists employed by a railway infrastructure manager as well as companies performing contract work in the construction and maintenance of railway infrastructure have access to modern technology. Legislation must therefore keep pace with the changing technology for the railway construction and management to become increasingly effective.



Wymiary właściwe i dopuszczalne odchylenia w mm

b	b1	c	c1	c2	c3	s	s1	e	e1	e5	e6	f	f1	f4	k	k1	m	g	g1	g2	g3	h	h1	i	i1	i5	i6
1445	1445	1435	1445,3	1435	1445,3	1435	1435	1435	1435	1435	1435	1394	1394	1355	1435	1435	56	70,7	77,6	77,6	70,7	41	41	44	44	40	40
+5	+5	+5	+5	+5	+5	+4	+4	+6	+6	+6	+6	+2	+2	+2	+5	+5	+4	+5	+5	+5	+5	+4	+4	+4	+4	+4	+4
-3	-3	-3	-3	-3	-3	-4	-4	-2	-2	-2	-2	-2	-2	-2	-3	-3	-2	-3	-3	-3	-3	0	0	0	0	0	0

Wymiary właściwe przechyłki i dopuszczalne odchylenia w mm

b	b1	c	c1	c2	c3	s	s1	e	e1	e5	e6	f	f1	f4	k	k1	m	g	g1	g2	g3	h	h1	i	i1	i5	i6
0	0	0	0	0	0	0	0	0	0	0	0				0	0											
±5	±5	±5	±5	±5	±5	±5	±5	±5	±5	±5	±5				±5	±5											

Wymiary zbadane w mm

b	b1	c	c1	c2	c3	s	s1	e	e1	e5	e6	f	f1	f4	k	k1	m	g	g1	g2	g3	h	h1	i	i1	i5	i6
1440,0	1442,1	1447,1	1447,7	1442,7	1449,6	1431,8	1427,6	1433,3	1434,5	1438,5	1442,1	1392,2	1392,5	1378,5	1433,0	1432,4	51,6	68,2	56,3	67,7	56,4	41,9	42,2	36,6	42,4	39,6	42,6
-4,3	2,2	-2,1	-3,2	-0,2	-1,3	8,2	-3,9	15,9	-8,8	-5,1	4,6				8,4	-1,6											
1440,5	1446,5	1434,9	1454,7	1431,7	1458,8	1438,9	1445,2	1435,7	1443,0	1438,2	1437,0	1397,4	1400,0	1378,4	1440,4		53,1	80,2	63,5	80,4	63,9	42,1	43,3	43,0	40,3	42,0	40,3
-0,5	1,4	0,2	3,6	1,3	5,1	6,8	-7,8	-12,7	-13,2	-3,0	6,1				8,8												

Fig. 4. Digital sheets for technical research of turnouts no.15, built in Słomniki station.

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