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Measurement of the geometric conditions of the visibility of the level railroad crossing*

Abstract: The article discusses the issues related to the visibility conditions of level railroad crossing - taking into account the author's measurements. The results of the work on the geometric visibility conditions were obtained with the use of the manual adapters used to mount the geodetic prisms on the manual or digital gauges. The measurements also used a magnetic-measuring device with a disc. The technical and operational documentation of a railway / road crossing or passage, called the rail / road crossing / passage meter, requires geodetic and diagnostic work. Obligatory preparation of this documentation leads to improvement of its quality and uniformity throughout the country. The article presents author's observations and conclusions. This work was performed within the statutory audit of AGH US 11.11.150.005.

Keywords: Level crossing; Grade crossing; Triangle visibility; Metric level crossing; Measurement level crossing; Pedestrian crossing; Cross-walk; Level railroad crossings

Introduction

The railroad can cross the public road in one level or in two levels. The railroad crossing is a crossroad in one level, which is not a transition [13]. A crossing is a crossing of a railway line or a siding with a road. The level railroad crossing is a one-level intersection of a circular road with a track or railway tracks. Level railroad crossings are divided into the following categories [13]:

1. A - level railroad crossings on which traffic is routed:
   - by qualified railway managers or railway carrier with required qualifications,
   - by means of manual signals or passive systems or equipment fitted with shutters that close the entire width of the roadway;
2. B – level railroad crossings on which traffic is driven by automatic transmission systems equipped with traffic lights and tollgate that shutting the traffic in the direction:
   - entry or passage
   - Entrance to the driveway and exit;
3. C – Level railroad crossings on which traffic is driven by automatic transmission systems equipped only with signaling lights;
4. D – Level railroad crossings that are not equipped with traffic protection systems and devices;
5. E – passages equipped with:
   - semi-autonomous passage systems or automatic transmission systems
   - turnstiles, barriers or labyrinths;
6. F - level railroad crossings or crossings located on internal roads, equipped in accordance with the requirements specified in [13] §12 paragraph 2.

Qualifying for a specific category depends on i.a. the number of main tracks that cross the circular road, and from the product of the traffic and the speed of the trains. The use of

level railroad crossings and crossings is permitted only on railway lines and railway sidings where the rail traffic is operated at a speed of no more than 160 km / h. In the paper [4], the number of single-level crossings on railway lines of PKP PLK S.A. as of December 31, 2014, it is clear from Table **1** that the most frequent railroad crossings are crossings classified in category D of 9378, which accounts for as much as 61% of all journeys and transits. The current state of the number of passes and crossings in the graphic interpretation is presented in the Interactive Map of Railway Lines. This map is, however, of an illustrative nature and can not be considered as an official document. By comparison, the number of railroad crossings administered by DB Netz AG in 2014 was 13777 [1]. This number is decreasing - in 2004 it amounted to 22881, and in 2013 already 18117 [2]. In the paper [3], the authors state that "one of the most dangerous elements of railway and road transport infrastructure, due to the intersection of one road and railway track, consists of railway crossings". Transport safety is one of the basic criteria for evaluating the functioning of the whole transport system, it determines its efficiency and the quality in the transport system [3].

Tab. 1.: Number of railroad crossings and passages [4]

Specification	railroad crossings and passages category						Razem
	A	B	C	D	E	F	
Total, including:	2602	862	1312	9378	527	727	15408
on operating lines	2516	856	1283	7158	494	593	12900

The article presents the geometrical conditions of the visibility of the railroad crossing, taking into account the author's measurements, based on the passage classified to category D. The number of journeys of this category on railway lines PKP PLK S.A. is the largest (Table 1). Category D railroad crossings include crossings of railway lines or sidings with public roads, as defined in Regulation [13].

The geometric conditions of visibility on rail and road crossings described in the article were carried out using the author's adapters used to mount geodetic prisms on manual or digital gauges. Also used is a magneto-measuring device with a disc. The article presents author's observations and conclusions. This work was performed within the statutory audit of AGH US 11.11.150.005.

Legal regulations on conditions of visibility of level railroad crossings

The basic law governing the conditions of visibility of the rail road crossings are the provisions of the Regulation of the Minister of Infrastructure and Development of 20 October 2015. On technical conditions to be met by the junction of railway lines and railway sidings with roads and their location. [13] The Regulation is an executive act of the Construction Law [18]. The report of the Supreme Chamber of Control (NIK) on traffic safety checkpoints and railroad crossings [12] stated, inter alia, that to reduce the level of safety at level crossings may have contributed to the introduction by the minister. Transport the provisions of this Regulation [13] without prior analyzes of the impact of the new regulations on rail traffic safety. Regulation [13] requires, among other things, The value of angles of crossroads with railways in a gradual measure (Annex No. 2 to the Regulation - rail road crossing / transit metrics) and refers only to such measurements of angles, without reference to other angular measurements, e.g. grad. Application of these regulations is mandatory in the design, construction, reconstruction, repair and maintenance of railway junctions and rail sidings with public roads and internal roads as well as during their use. However, they do not apply to crossings of railway lines and railway sidings with internal roads and service crossings of the railway infrastructure manager. Legal regulations [13] mandate the preparation of technical

and operational documentation for rail road crossings or transits called rail road crossing metrics/ passage. This documentation improves the quality and introduces uniformity through the use of typical national design and typical designs whose content, form and accuracy are derived from the technical requirements of a given specialty - railway infrastructure. The results of geodetic and diagnostic work on specific content (by regulatory requirements), accuracy and form for a given type or group of needs are called typical designs. In addition to the basic data on travels or transits, you must obtain data entries that are the result of geodetic work and diagnostic work. Typical geodetic works include:

- determining the current longitudinal slopes of the road on the way to the track (with the direction of tilt),
- measurement and determination of the crown width of a road at a railroad crossing or passage,
- measurement and the determination of the width of the road on a rail road crossing or passage,
- measurement and the determination of the width of the roadway,
- measurement and determination of the length of a railroad crossing or passage,
- measurement and the determination of the angles of intersection of the railway road served mainly gradual,
- Drawing of roadside scenery or crossings (with measurement and demonstration of obstacles to road visibility), transverse sections, visibility triangles for categories D and E,
- measurement and demonstration of the visibility of the front of the train at distances of 5, 10 and 20 m (distance measurement is made from the extreme rail),
- measurement and the determination of the distance between track axis (intertrack),
- measuring and showing the visibility of a railroad crossing or crossing from a road.

Typical obstacles limiting the visibility of the train's face from the circular road crossing with the railway road are mainly forests, shrubs, buildings, slopes. The rail manager is required to produce, maintain and maintain a metric. This document should be kept for the entire duration of use of the railroad crossing or passage. Additional requirements for visibility conditions for rail and road traffic are based on the instructions and technical conditions of Id-1 (D-1), Id-3, Id-7 (D-10) [5] [6] [7] [16].

The geometric conditions of visibility of the rail road crossings for two and more tracks

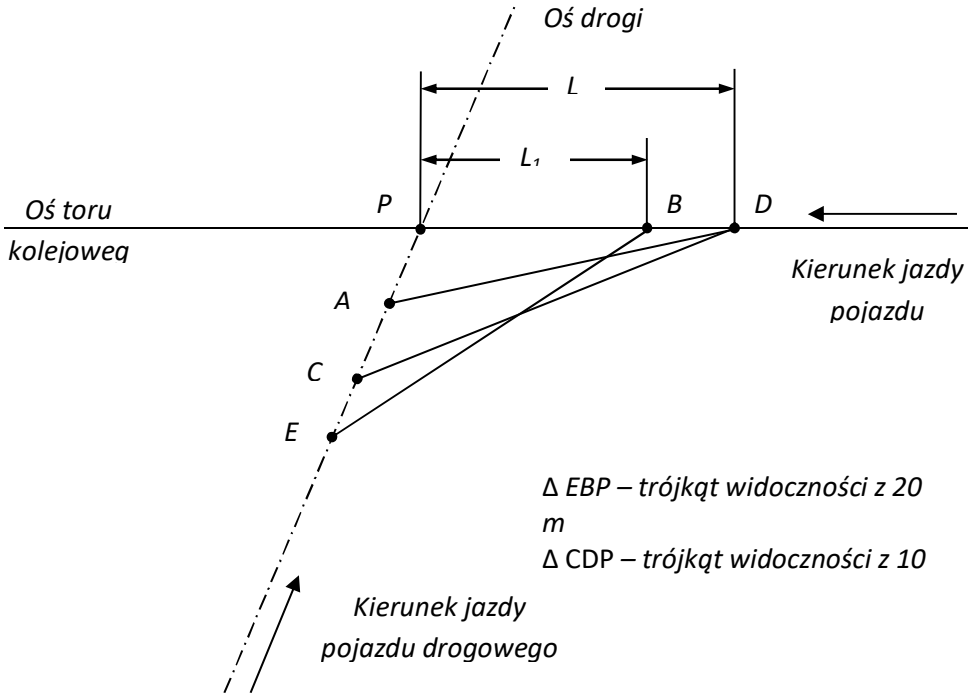
Road and rail crossing geometry should ensure visibility, allowing rail and road traffic safety. Both railway and road managers are required to check the visibility conditions:

- once a year, after a period of vegetation growth, i.e. between June and September,
- after every accident.

Under normal weather conditions, the face of the approaching train, and at least the signal lanterns of its face, should be visible to drivers driving from a distance of 20 m (point E) (Figure 1), measured from the extreme rail along the road axis, D category 3A of the Regulation [13] defines the geometric rules for checking the visibility of a train's face from a public road before a rail road crossing, so called triangle visibility (Fig.1).

From point E the train face should be visible from point B (fig. **1**). As the road vehicle approaches the rail road crossing, the train's visibility should increase so that at least 10 meters from the extreme rail (i.e. from point C) the train's face is visible from point D. The visibility of the train from the public road is determined for both sides of the railway road crossing [13]. Visibility of the train should be checked in conditions similar to those of road users. The track of the approaching train is monitored from a height of 1 ÷ 1.2 m above the lane axis of the road. In cases justified by local conditions, if the passage of category D does

not meet the visibility conditions from the observation points E and C, the train face should be visible from the public road at least from a distance of 5 m from the extreme rail (observation point A) throughout the L section, from point D (fig.1). In a situation where for a given speed of the train is maintained only visible from a distance of 5 m, to be on the road from both sides of the railroad crossing category D set road sign B-20 "stop".



1. Geometric conditions for checking the visibility of a train's face from a public road before a railroad crossing - visibility triangles (based on [13])

The lengths of the visibility of the face of the train from the public road L and L1, in accordance with the signs given in Figure 1, for railroad crossings through two- and multi-track, are determined according to formulas (1) and (2).):

$$L = (5{,}5 + 0{,}25 \cdot d) \cdot V_{max} \tag{1}$$

where:
V_{max} – maximum permitted train speed in the area of railroad crossing [km/h],
d – the distance between the axes an extreme and the next track [m].

$$L_1 = (3{,}6 + 0{,}07 \cdot d) \cdot V_{max} \tag{2}$$

where:
V_{max} – maximum permitted train speed in the area of railroad crossing [km/h],
d – the distance between the axes an extreme and the next track [m].

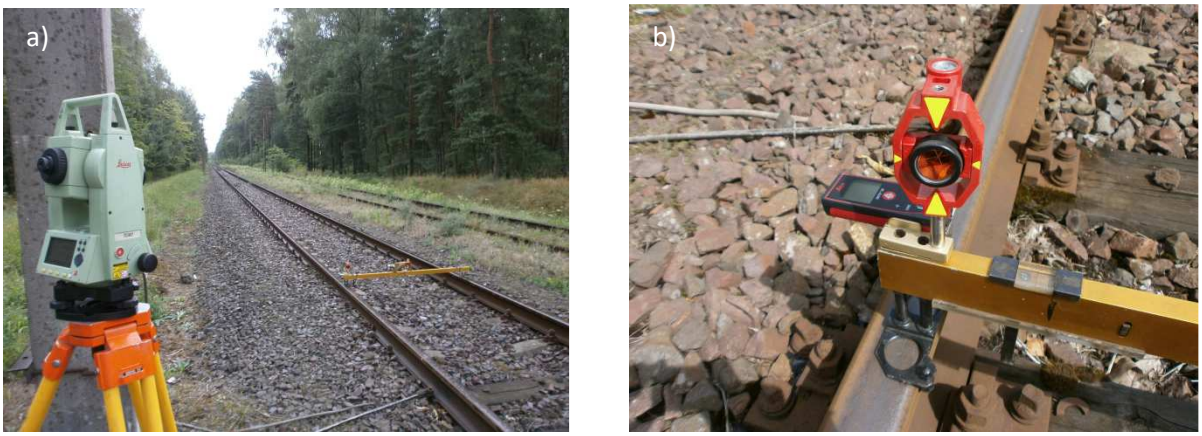
For calculation of linear value L and L1, Vmax is assumed to be a speed of not less than 40 km / h on normal rails, even if the maximum allowed speed on a given line would be less [13, 14, 15]. The visibility of the area occurring within and near the triangles of visibility should not be limited by the presence of buildings, trees, shrubs, other high-tech crops, advertisements and acoustic protection elements.

Adapters of geodetic prism mounts on the tachometer

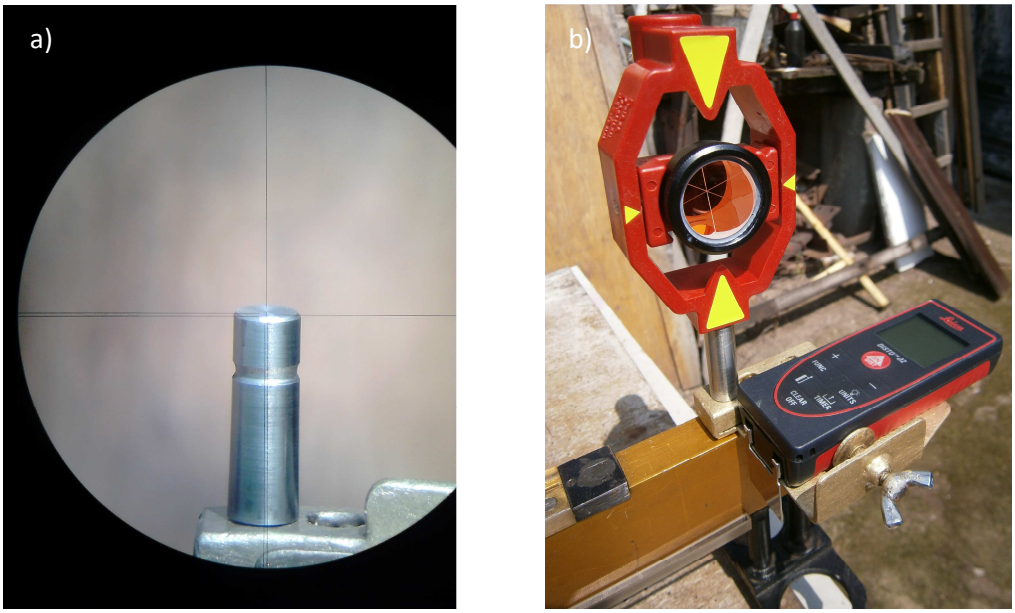
The measurements were carried out using the adapters used to mount geodetic prisms and the laser rangefinder or specialized laser pointer (fig. **2**). Adapters allow geodetic installation:

- Standard prisms (round) GPH1 + GPR1,
- prisms 360° GRZ4,
- miniprisms 360° GRZ101,
- miniprrisms GMP101/102,
- miniprisms GMP111,
- miniprisms TPS112A,
- pryzmatów Wild GPH1P,

in such a way that their vertical axles coincide with the inner edges of the rail head in manual and digital torches. This solution allows to reflect the existing track axes or axes of crossings and crossings. In the field of geodetic work, miniprizations of the GMP111 type with manual torque meter and TC407 Leica tachymeter no. 697413 were used (Figure **2-3**). Miniprisms allow for accurate measurements of execution, stocktaking and are helpful in the postmortem. In the tachymeter there is a possibility to set different distance measurement modes. Depending on the mode selected, the headlamp should be adjusted accordingly. Fine-tuning (IR-dokł) for precise measurement of the distance to the prism is 2 mm + 2 ppm [8] [11]. Wherein the high vibrations occurring air moving objects within the beam path or beam interruption can result in deviations of the specified accuracy. The standard deviation of the Hz measurement - horizontal direction, V - vertical angle / zenith angle (ISO 17123-3 [10]) for TC407 is 7 '(20cc) [8]. As a result of the small diameter of the prism, the accuracy of the measurements is increased and the mounting of the miniprimators on the torch through the adapters ensures spatial identification of the existing track axes, and in the case of turnouts the axes of the turnouts. Measurement of the building gauge for railway infrastructure elements (traction poles) and the cross-check of the crossings were also made using the DISTO ™ D2 Leica laser range finder (Fig. 2b), together with the target plate (Figure 4). The laser rangefinder is mounted using a geodetic prism mount adapter on the track gauge, the rear face of the rangefinder is aligned with the edge of the rail head (Figure 3b). In order to measure the width of the cross-section, a magnetic-measuring square (MMS) with a measuring disc (fig. **4**) was also used, whose vertical axis coincides with the head edge of the rail [9].



2. Measurement of geometric visibility conditions for railroad traffic: a) TC607 Leica tachymeter, b) adapter mounted with GMP111 miniprism and with laser rangefinder on manual gauge



3. Mounting method on the tracker: a) geodetic pin, b) laser rangefinder

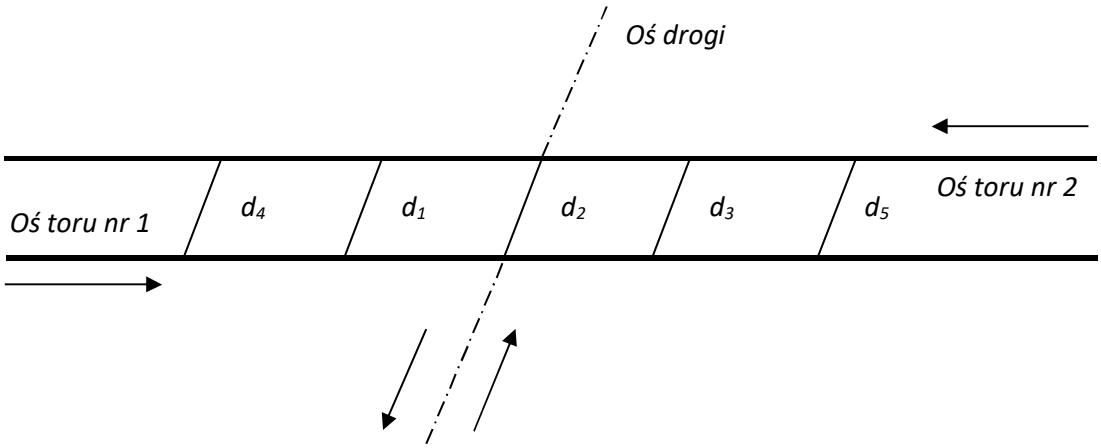
4. Magnetic measuring square with measuring disc

Existing geometric conditions of Category D passage visibility

The railroad crossing is located near the border of the Silesian and Opole provinces, on the Borowiany - Kielce route at 22,800 km, in the village Krupski Młyn in the district of Tarnow. It is classified in category D and has two main tracks in a straight line. The driveway is located in an undeveloped area. In order to determine the distance between the track centers, it was measured at the beginning, end and axis of the concrete slabs, which cover the passage, arranged inside and outside tracks 1 and 2. Additionally, the measurement of the crossroads was made at a distance of 10.0 m from the beginning and end of the passage Table **2**, Fig. **5**).

Tab. 2: Existing values of distances between track centers 1 and 2

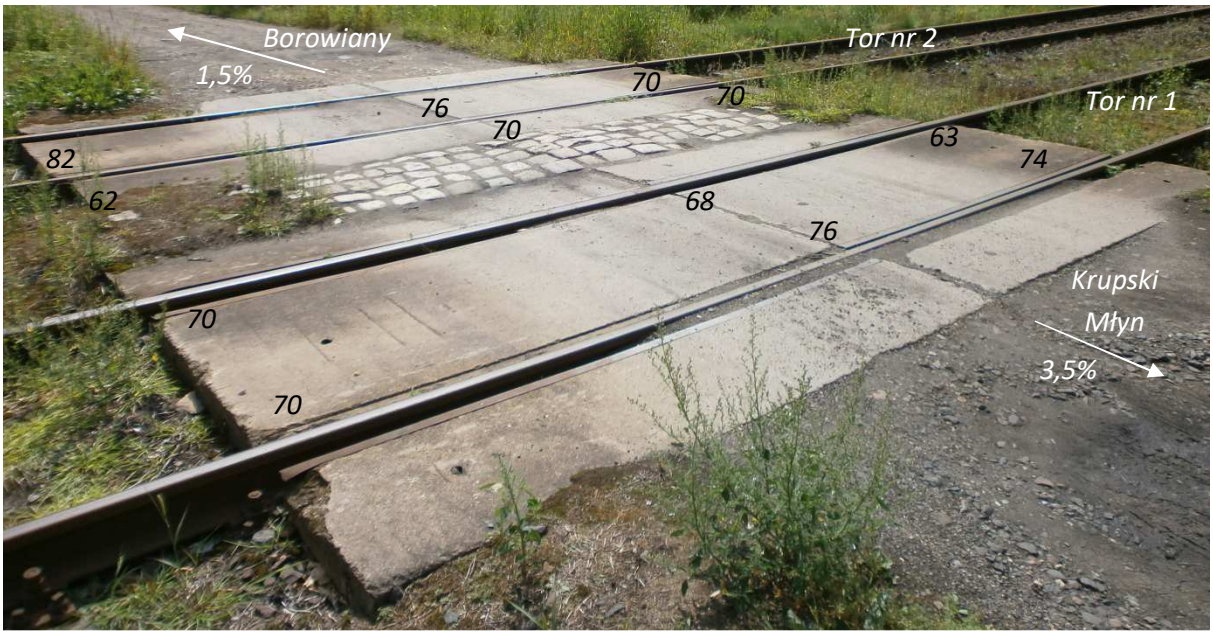
Measurement point number	The value between the tracks d_i [m]
d_1	3,987
d_2	3,979
d_3	3,910
d_4	3,984
d_5	3,970
Avarage value d	3,966



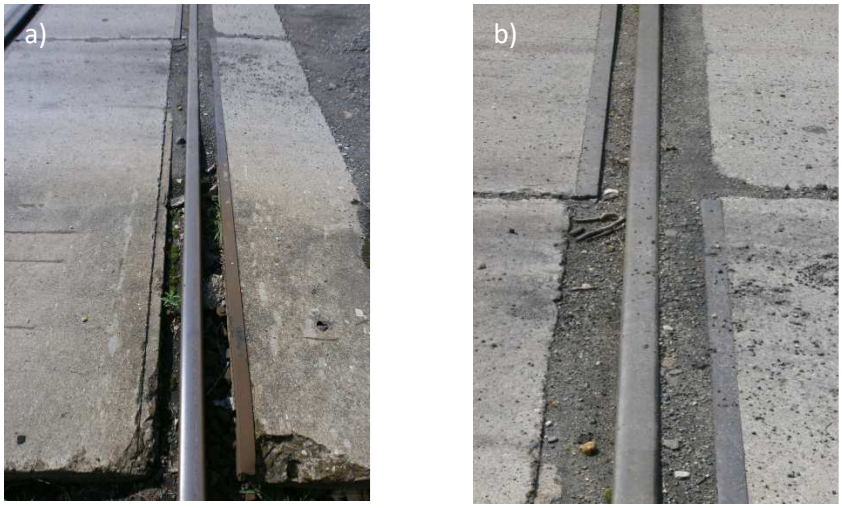
5. Location of existing distance values between track centers 1 and 2

The lengths of the L and L1 train track visions as shown in Figure 1 (formulas 1 and 2) for journeys through two tracks taking into account the speed Vmax = 40 km / h are L = 259.66 m, L1 = 155, 11 m.

Measurement of the width of grooves on a rail-road crossing was made at a height of 14 mm below the top of the railhead. In accordance with Recommendation [13] (Chapter 3: "Design of rail and road crossings"), their width shall be not less than 60 mm in straight and curved lines of 350 m or more. According to the repealed Implementing Act [14] this value was 67 mm. The existing width of the grooves on the basis of the measurements is shown in Figure **6**. However, the depth of the groove at the maximum permissible rail wear, measured from the surface of the rail head, shall be not less than 38 mm. Unfortunately, this condition is not fulfilled (Figure **7**), there are also profiled edge reinforcement plates. Studies have shown inconsistencies in Regulation [13] and Id-1 (D-1) [5]. According to Id-1 (D-1) [5] § 13 5 the construction of the pavement inside the track should ensure the free passage of the wheel rim of the rolling stock. For this purpose, at least two rails inside the track shall be made with a depth of at least 38 mm (at the maximum permissible vertical wear of the rails) and a width of at least 67 mm on the straight track and in arcs with a radius R> 350 m, with a track width not exceeding 1445 in operation. mm. According to Regulation [13], the width of the grooves shall be not less than 60 mm in straight and curved lines of 350 m or more.



6. Criteria widths and longitudinal gradients on railroad crossings of category D Krupski Młyn - Borowiany / Radun (values in mm and%)



7. Condition of plates in track No. 1 constituting the passage cover, arranged inside and outside of tracks No. 1 and 2: a) torn profile reinforcement of the inner board, b) improper depth of grooves (filled up)

The distance of the rail contacts from the extreme elements of the runway surface shall not be less than 6,00 m, and the electrowire or thermite welds shall not be less than 3.00 m [5] - in track 2 there are rail contacts at a distance less than 2.0 m from extreme elements of the road surface (fig.8).

Road signs: B-20 "stop" and G-4 "cross St. Andrzej before the multi-track railway "are located correctly, from two directions of the journey. The length of the railroad crossing is the length of the section, the end points of which are determined at adistance of 4.0 m from each of the extreme rails, is 13,573 m. The width of the rail-road crossing is the width of the crown of the road at the railroad crossing and is equal to 6,013 m. The existing longitudinal inclination of the access road to track 1 (right side) at length of 20.0 m is 3.5% and to track 2 (left side) at length of 20.0 m is 1.5% (Figure **8**).).

8. Distance of rail contacts from the extreme elements of the road surface

Cross-sectional angles are shown in Tables **3** and **4**. The existing smallest crossing angle is 81 °. The geometric conditions of the visibility of the railroad crossing have been preserved.

Tab. 3: Geometric conditions of visibility of the train's face from track 1

Measurement date	Measurement of visibility conditions from the road (distance measured from the extreme rail) [m]						Average distance between track axes "d" [m]	Speed of "V" trains in the area of railroad crossing [km/h]
	5 m		10 m		20 m			
	track side		track side		track side			
	right	left	right	left	right	left		
	to the right [°]	to the left [°]	to the right [°]	to the left [°]	to the right [°]	to the left [°]		
29.07.2016 r.	88	90	90	87	93	86	3,966	40

Tab. 4: Geometric visibility of the train's face for track 2

Measurement date	Measurement of visibility conditions from the road (distance measured from the extreme rail) [m]						Average distance between track axes "d" [m]	Speed of "V" trains in the area of railroad crossing [km/h]
	5 m		10 m		20 m			
	track side		track side		track side			
	right	left	right	left	right	left		
	to the right [°]	to the left [°]	to the right [°]	to the left [°]	to the right [°]	to the right [°]		
29.07.2016	99	84	102	82	100	81	3,966	40

Summary

Based on the tests carried out using adapters used to mount geodetic prisms on manual or digital gauges and the example of the MMS with the shield, the application of the presented solutions in the measurement of the geometric conditions of the visibility of railway and road crossings results. The road-to-road crossing should correspond to the visibility conditions, which are determined by the visibility triangle. Number of railroad crossings of category D managed by PKP PLK S.A. is the largest and they are among the most commonly used in Poland. It is therefore reasonable to carry out geodetic and diagnostic measurements at rail

and road crossings, especially in this category. The work was presented on a regular basis, but it should be pointed out that:

- the lower the angle of crossroads in one level, the longer the road where a collision of vehicles traveling on these roads may occur,
- entry into Id-1 (D-1) [5] § 13 Maintenance and protection of road junctions with railway lines in the level of rails, including firewalls, signaling devices, railway signs as well as road surfaces in the area between the toll gates, and in the absence of them - at a distance of 4 meters from the extreme rails, belongs to the railway management - is in compliance with art. 28.1 of the Act on Public Roads of 21 March 1985 [17],
- Regulation [13] introduces a time limit for the reclassification of rail and road journeys. Within 5 years from the date of entry into force of the Regulation [13], the railway manager is obliged to change the category of rail and road journeys and adjust the traffic protection systems on these journeys to the requirements set out in the Regulation [13]. Railway-to-road traffic regulations should be classified as non-current,
- the geometric conditions for the visibility of rail and road journeys should be maintained with the proper visibility of the visibility triangles,
- implementation of the latest technical and engineering solutions in the field of geodetic and diagnostic measuring methods and techniques facilitates the maintenance and updating of railroad crossing / passing metrics,
- The number of railroad journeys administered by DB Netz AG in 2014 was 13 777 [1]. This number is gradually decreasing - in 2004 it amounted to 22,881, and in 2013 already 18,117 [2]. For PKP PLK S.A. The total number of journeys is 15 408 [4]. Too many railroad journeys result in unreasonable costs and lowers road safety.

The results of works using geodetic prism mounts, laser rangefinder or special laser pointer on the tachometer, as well as the magneto-measuring device with the shield are included in the subject matter of modern research in the discipline of engineering geodesy and industrial construction diagnostics.

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