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Research paper

Selected problems of design and construction of the 19th century railway bridges by example of Ivangorod–Dąbrowa Railway

Wiktor Wciślik[1], Maciej K. Cichoń[2]

Abstract: The present paper discusses selected issues related to the design, construction and operation of 19th century railway bridges in the Kingdom of Poland. Individual problems are discussed on the example of the Ivangorod–Dąbrowa Railway (IDR). The route as a whole is characterized, along with a discussion of statistical data regarding the bridges located along the line in question. The competences of private and then state institutions in the field of railway construction are discussed synthetically, taking into account the impact of military issues on the design of railway routes and bridges in the country. The legal regulations that standarized the issues of design, construction and operation of railway bridges at that time, both technical and formal are characterized. The basic principles of hydrological calculations used to determine the clear areas of bridges and culverts of the railway are presented. A separate chapter is devoted to selected issues of structural design, with particular emphasis on the service load calculation (rolling stock and wind). The changes in legal regulations introduced during the construction of the IDR and in the preceding years are presented. Technical specifications and construction requirements for spans and supports are described. Selected types of unified bridges as well as individually developed designs of structures on the Vistula and Pilica rivers are presented. The then requirements related to proof tests and ongoing maintenance of railway bridges are also discussed.

Keywords: 19th century bridge, railway, steel structure, structural design, viaduct

[1]PhD., Eng., Kielce University of Technology, Faculty of Civil Engineering and Architecture, Al. Tysiąclecia Państwa Polskiego 7, 25-314 Kielce, Poland, e-mail: wwcislik@tu.kielce.pl, ORCID: 0000-0002-6586-5019
[2]PhD, Jan Kochanowski University, Stefan Żeromski St. 5, 25-369 Kielce, Poland, e-mail: makhon47@gmail.com, ORCID: 0000-0002-6952-7607

1. Introduction

Nowadays, the great importance of transport infrastructure, including railways, for the proper functioning of society and economy is obvious. The 1820's are considered to be the beginning of the era of modern transport, when G. Stephenson presented the first fully functional steam locomotive. This and other inventions gave rise to the industrial revolution, firstly in England and other Western European countries, and then in other parts of the world, including today's Poland.

The benefits of rail transport were quickly appreciated, primarily the ability to transport large loads over long distances, with relatively low cost and in timely manner [1]. These features turned out to be crucial for the dynamic development of industry as a whole.

The expansion of railway transport had to be accompanied by the dynamic development of bridge technology. The growing railway infrastructure required overcoming increasingly larger and complex obstacles, moreover the weight of the rolling stock gradually increased. Many bridges built at that time still function today and are the subject of intensive structural and material studies [2–6]. In this case, structural health monitoring becomes particularly important [7,8].

The increasing complexity of technical problems accompanying the development of bridge engineering resulted in the need to develop detailed regulations, standards and guidelines, concerning the processes of design and construction of railway bridges already in the 19$^{\text{th}}$ century.

This article characterizes selected issues of the design and construction of railway bridges in the 19$^{\text{th}}$ century Kingdom of Poland, on the example of the bridges of the Ivangorod–Dąbrowa Railway. Due to the limited volume of the work and the fragmentary nature of the materials found in Polish and Russian archives, the work is selective and of review in nature.

2. Ivangorod–Dąbrowa Railway

Ivangorod–Dąbrowa Railway [Polish: Droga Żelazna Iwangorodzko–Dąbrowska, Russian: Ивангородо-Домбровская железная дорога, hereinafter in text as IDR] was the longest railway in the Kingdom of Poland in Russian partition territory. The line started in Dęblin (then known as Ivangorod, fortress guarding railway crossing on Vistula river), from where the tracks ran through Radom and Kielce to Dąbrowa Górnicza, where it branched and connected to local coal mines of the Dąbrowa Bassin and adjoining railways of German and Austrian partitions. Whereas repeating the course of the Kamienna river it ran from Skarżysko-Kamienna (then Bzin) branching in opposite ways to Ostrowiec and to Koluszki: a Warsaw-Wien Railway station, servicing numerous steelworks and other plants of metallurgical industry. More information about the IDR line can be found in [9].

Over the course of construction about 400 bridge structures were erected. With start of the operations in 1885 there were 324 bridges of different construction and building material, with additional 14 on sidetracks to the partition borders (in 1900 overall number dropped to 316, probably due to substitution of some with culverts or bridges with longer spans [10–13]). In 1885 of the number of bridges 94 were small wooden ones, 29 vaulted stone and 201 iron bridges (with 5 wooden temporary still in use) with total clearance of 2 583 m. All wooden bridges were gone by 1900.

3. Legal regulations

Basic guidelines for routes of the railway line in 2nd half of the 19th century were processed on various levels of administration, from Warsaw governor-general and head of Warsaw Communication District, Inspector for Communications in the Kingdom of Poland, whose opinion if positive allowed the project to be presented before the Railway Building Commision of combined representatives of Ministries of Communications, War, Finances, State Property, State Control and in IDR case Warsaw Communication District and Kingdom's industry and financiers. Deliberations among said body and prospect shareholders produced framework of new project, and was written into future association's concession. Final provisions came into force with the signing of then reigning tsar, Alexander II (1818–1881, reign 1855–1881) and printing in the Digest of Laws of the Russian Empire and Digest of Laws of the Kingdom of Poland [14, 15].

Technical provisions and conditions for railways resulted primarily from military conditions – strategic use of railways and state security, and only then economic needs. Overall unified look of structures in the Empire was also a factor. Locally however, mountainous terrain was the most important, influencing the course and volume of works: firstly Świętokrzyskie Mountains and secondly Kraków-Częstochowa Upland with their numerous rivers and watercourses. Means for carrying out works were investigated by field examination commissions of the IDR Association and Ministry of Communications. Their conclusions were basis for said Ministry level commission, which concerned itself with both construction practice and already codified guidelines and characteristics of rail infrastructure as well as final inaccuracies in the route of the line and the location of its bridges [15–20]. The fruit of their labor were "Technical conditions for the construction and operation of the Ivangorod-Dombrovskaya Railway" published in 1881 and then with amendments in 1882 [21, 22]. These went into effect with signature of Minister of Communications, Konstantin Nikolayevich Posyet (1819–1899, in position 1874–1888).

4. Hydrological analyses

The construction of the IDR was processed shortly after the famous Kukuevka disaster in Russia (1882), which was directly caused by the incorrect determination of the culvert cross-section [23].

The consequence of the disaster was the introduction of revised, more rigorous regulations regarding the hydrological design of bridges and culverts. Bridges along the IDR were designed based on new regulations, which resulted in a high ratio of the clear span per unit of route length, amounting to 5.6 m/km (2.8 fathoms per verst). For comparison, in the case of the Nadwiślańska Railway, designed according to the previous standards, with more complex terrain conditions and a larger number of catchments, this coefficient was only 3.88 m/km (1.94 fathoms per verst).

Another consequence of new regulations was the replacement of pipe culverts with bridges. The adopted catchment characteristics were based not only on map analyses, but also on detailed field research, conducted mainly by rail own engineers and communication students [24, 25].

The changes to the regulations were gradual and were initiated by the introduction of ministerial guidelines on October 12th, 1882 [12]. It stated that the clear span of bridges and culverts should be designed for a flow corresponding to 3 hours of rainfall, with 3.81 cm

(1.5 inch) layer of water per 1 hour. This meant that every square verst of the catchment area corresponded to the flow of 9.72 m^3 (1.25 fathom^3) of water per second.

As the flow under the bridge depends on the catchment area, relief, land development, etc., according to the regulations at that time, this value had to be adopted in accordance with Table 1, as the function of the catchment area:

Table 1. Determination of the maximum volumetric flow under the bridge [12]

Catchment area [km^2]	0.7	0.9	1.1	2.3	3.4	4.6	5.7	6.8	8.0	9.1	10.2	11.4	17.1	22.8	34.1	45.5	56.9
Maximum flow [m^3/s]	7.3	8.3	9.3	13.0	15.7	18.1	20.0	21.9	23.3	24.7	26.0	27.2	32.3	36.4	42.6	47.4	51.2

Having the flow under the bridge determined according to the table above, it was possible to calculate the clear area under the bridge, using the formula:

$$A = \frac{Q_{\max}}{v} \tag{4.1}$$

where: $Q_{\max}$ – maximum water flow under the bridge, expressed in [m^3/s], according to Table 1, v – assumed flow velocity under the bridge, for example, in the case of paving the bed under the bridge, the admissible velocity was 3.2 [m/s] (1.5 [fathoms/s]).

The above recommendations were applied to small watercourses for which the flow parameters at the intersection of the watercourse and the railway under construction were unknown. In the case of watercourses with a large catchment area, the results of measured flow values in the natural riverbed at the highest water level were used to determine the bridge span. Then, the necessary clear span was calculated from the following formula:

$$b = \frac{Q}{0.95aV + 1.92\left[(h+k)^{1.5} - k^{1.5}\right]} \tag{4.2}$$

where: Q – measured volumetric flow at the highest water level, a – the maximum depth of water impounded under the bridge, V – average flow speed under the bridge, h – water impoundment under the bridge, k – slope corresponding to speed V.

In practice, due to the introduction of subsequent changes in regulations, as well as the uncertainty of the measured values, the clear spans of the bridges along the IDR were considerably larger than calculated. In some cases, due to the impossibility of accurately determining the flow and bridge clearance, temporary wooden bridges were built and replaced with permanent ones after long-term hydrological observations.

5. Structural design

During the construction of the IDR, subseqent updates in standards regarding structural design were released. The key issue was the adoption of service load scheme for static analysis. This primarily resulted from the introduction of heavy four-axle steam locomotives. In the guidelines of the Ministry of Communication of June 6th, 1881, it was recommended to adopt the set of concentrated loads to determine the structure internal forces, instead of the previously applicable uniformly distributed loads [12]. The system of these concentrated forces was supposed to reflect the load of a train composed of three steam locomotives with tenders and a number of cars. The load diagram is illustrated in Fig. 1.

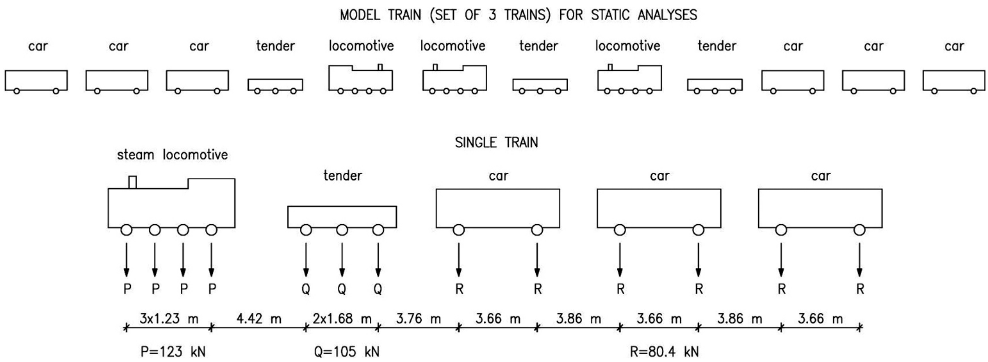

Fig. 1. Single track loading with a model train, according to the ministerial guidelines of June 6th, 1881 [26]

All bridges on the IDR were designed in accordance with the above scheme, although shortly after the completion of the design work, on January 6th, 1884, a new ministerial standard was released, which allowed the design of railway bridges, assuming an uniformly distributed equivalent load. The main goal of the new regulations was to simplify static calculations.

The values of distributed loads were derived basing on the diagram in Fig. 1. The maximum bending moments and shear forces were determined at specific span sections, subsequently the obtained values were compared to the results for the continuous loading scheme. As a result, different equivalent load values were obtained for determining shear forces and bending moments, separately for different effective spans (Table 2). For intermediate spans, linear interpolation of load values was used.

The standard of 1882 [22, 27] also specified the principles for wind loads calculation in the design of railway bridges. Already then, it was mandatory to distinguish two schemes, namely the case of wind impact on an unloaded span and one loaded with railway rolling stock. In the first case, uniform pressure with an intensity of ~2.3 kPa (1.3 poods per foot^2) was assumed. In the case of truss bridges, the wind impact area was assumed to be 0.6 of the area limited by the truss contour.

In the latter case (span loaded with rolling stock), the pressure exerted by the wind on the train had to be added to the pressure determined above, assuming that each foot of the bridge's length corresponds to 0.7–0.93 m^2 (7.5 to 10 feet^2) of wind action area (depending on the structural system and the height of the structure). An additional load with an intensity of 0.6 of the load determined for the unloaded span was applied to the area determined in this way.

Table 2. Equivalent uniform loads per single track, according to the ministerial standard from 1884 [12]

Effective span [m]	**Distributed load per single track [kN/m]**		
	For calculation of bending moments and shear forces at the supports	**For calculation of bending moment in the middle of the span**	**For calculation of shear force in the middle of the span**
2.13	194.41	140.71	280.88
4.27	151.98	124.06	193.87
6.40	129.43	113.32	164.87
8.53	99.35	90.22	138.02
10.67	81.63	71.43	118.15
12.80	76.80	63.91	107.95
14.94	74.11	60.15	97.74
17.07	71.43	57.46	90.76
19.20	68.74	56.39	85.39
21.34	67.13	55.85	82.17
25.60	63.91	55.32	76.80
32.00	61.76	54.24	70.35
42.67	58.00	52.63	64.98
53.34	54.78	51.56	62.30
64.01	51.56	49.95	60.15
74.68	48.87	47.80	58.54
85.34	47.26	45.65	57.46
96.01	45.11	44.04	56.93
106.68	43.50	42.43	55.32
117.35	41.89	40.82	54.24
128.02	40.82	39.74	53.17
138.68	39.20	38.67	51.56
149.35	38.13	37.59	50.48
160.02	37.59	37.06	49.41

In the context of wind loads, the ministerial regulations also provided rules for designing horizontal truss chords. The cross-sections of such elements had to be designed with respect to the following condition:

$$A \geq \frac{P + 0,6P'}{R} \tag{5.1}$$

where: A – chord cross sectional area, P – force in the chord resulting from vertical load (weight of structure and rolling stock), P' – force in the chord of horizontal truss (resulting from wind operation), R – maximum permissible stress.

Two cases had to be considered. In the first case, the wind load was not taken into account ($P' = 0$). Then the R value was 71.06 MPa (285 poods per inch^2). In the second case (taking into account the effect of wind), the permissible stress was set at $R = 74.8$ MPa (300 poods per inch^2).

As stated in [27], changes in regulations introduced after 1882, in addition to the above-mentioned hydrological issues, resulted in an approximately 30% increase in material consumption, which was a direct result of much more restrictive assumptions regarding operational loads.

6. Specifications and unified (catalog) structures

6.1. Specifications

In the Kingdom of Poland, the requirements for the design and construction were formally issued by the Ministry independently for each route under construction, although individual documents were characterized by many common, repeatable schemes.

Detailed guidelines for the construction of the IDR were included in [21,22]. Chapter V of this document was devoted to the issues of design and construction of bridges and viaducts.

According to it, the span was to be designed for a single track, although abutments and piers had to be widened, which would be sufficient for a possible future construction of the second, parallel bridge.

Stone, brick and steel were recommended as construction materials. The use of wood was allowed in temporary structures and permanent ones with a span not exceeding 2.13 m (1 fathom).

Bridges longer than 14.94 m (7 fathoms) were required to be built on straight sections of the route. Balustrades were demanded for bridges longer than 4.27 m (2 fathoms). At the request of the Ministry of Communication, the bridges and viaducts were equipped with entry barriers on both sides.

The issue of the foundation design was characterized generally. The only requirement was the necessity of using caissons for bridges over the Vistula and Pilica rivers. The backfill of the abutments should be made of stone, sand or other dry and non-clay soil [21,22].

The supports were recommended to be made of stone, requiring their upper edge to be at least 1.07 m (0.5 fathom) above the high water level on non-navigable rivers. The elements supporting the metal parts of the span, were required to be made of hewn stone.

In the case of metal bridges, stone supports had to be built using cement mortar. A separate provision in document indicated that the cement used for construction had to be produced in the Russian Empire.

In terms of structural design, specifications required taking into account the load of eight-wheeled steam locomotives with an axle load of 12.5 tons and a wheelbase of 1.23 m. In turn, the cross members had to be designed for an axle load of 15 tons.

Since specifications were issued separately for each railway, it was possible to formulate not only general guidelines, but also rules for specific bridges and viaducts. For example, the bridge over the Vistula was required to be adapted to both rail and road traffic. The required road vehicle loads that had to be taken into account during design were listed in detail in [21, 22]:

– four-wheeled carriages with a load of up to approx. 9828.4 kg (600 poods), with a wheelbase of 3 m, axle length of 2 m and rim width of 13 cm,
– two-wheeled carriages with a load of up to approx. 7371.3 kg (450 poods), with a wheelbase of 1.6 m and a rim width of 13 cm,
– four-wheeled carriages with a load of up to approx. 1474.26 kg (90 poods) and a rim width of 13 cm.

In turn, it was required that the horizontal clearance under viaducts should be at least 5.34 m for roads, rural streets, provincial and district roads, and not less than 3.2 m for rural and field roads. In the case of roads in cities, these requirements were individually set by the Ministry of Communication [21, 22].

In terms of material assumptions, the supports for railway viaducts over roads were required to be made of stone, and the spans based on them had to be made of stone or metal.

In the case of road viaducts located over railway tracks, it was recommended to use wooden spans based on stone or wooden supports.

6.2. Catalog structures

As mentioned above, in the Kingdom of Poland during the construction of the IDR, the legal regulations were very precise and did not allow for creative design of the structure. This concerned both the principles of hydrological and structural calculations (discussed briefly in previous subsections) as well as the structural systems used. For example, the use of continuous beams or trusses with curved chords was not accepted [27].

The structural and material descriptions of the bridges of the IDR were presented in detail in "Drawings of Ivangorod–Dąbrowa Railway" [19]. Its content can be divided into two chapters: drawings of typical, repeatable bridges with specific spans and bridges designed individually for a given location.

Generally, the first group includes technical drawings for bridge spans of 2.13, 4.27, 5.34, 6.40, 8.54, 10.67, 12.80, 14.94, 21.34, 25.61, 32.01, 42.68, 64.02 meters (respectively 1, 2, 2.5, 3, 4, 5, 6, 7, 10, 12, 15, 25, 30 fathoms). Additionally, drawings of stone abutments for bridges with clear spans of 3.20, 4.27, 5.34, 6.40, 8.54, 10.67, 12.80, 14.94 meters (respectively 1.5, 2, 2.5, 3, 4, 5, 6, 7 fathoms) were developed, provided that their foundation should always be adapted to local ground conditions.

Structural designs for bridges on the Vistula, Pilica, Wolbórka and, for a temporary wooden bridge on the the Nida were individually developed. Moreover, drawing documentation for the viaduct over the tracks of the Warsaw-Vienna Railway at the Strzemieszyce station and the pedestrian footbridge at the Koluszki station were also presented.

With clear spans of 2.13, 3.20 and 4.24 m, the engineering structures were designed as vaulted culverts. For larger spans rolled steel bars and plate girders as well as truss systems were used, primarily the Howe system.

Examples of typical bridge structures with a clear span of 1 and 6 fathoms are presented in Figs. 2 and 3, respectively.

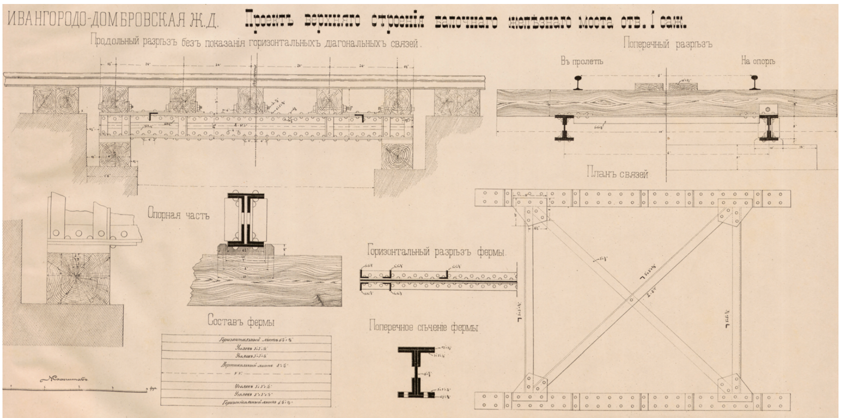

Fig. 2. Typical bridge with a clear span of 1 fathom, compiled by S. Zieliński [19]

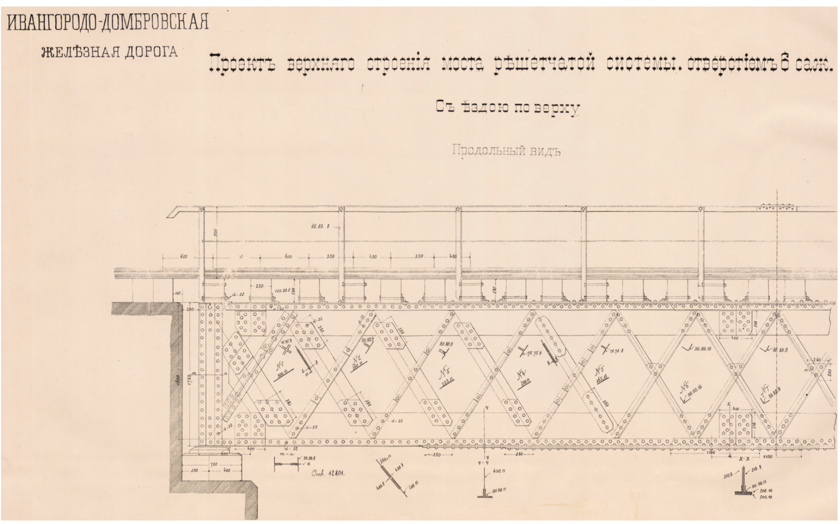

Fig. 3. Typical bridge with a clear span of 6 fathoms, compiled by S. Zieliński [19]

7. Examplary bridges of the Ivangorod–Dąbrowa Railway

As mentioned above, the document [19] regardless of repeatable, typical bridges, presented individually developed design drawings for the most demanding and complex cases. Most sources atribute authorship of these structures to Stefan Zieliński, although it has to be stated, that he worked with both groups of other engineers and body of work of Nikolai Apollonovich Belelubsky a prolific railway and civil engineer, himself author of many typical bridge structures and bridge building methodology. However, Zieliński's signature is reproduced on schematic drawings, i.e. of Pilica and Vistula bridges. Said objects over these rivers are briefly characterized below.

7.1. Bridge over the Vistula river

The largest bridge on the entire IDR was a five-span bridge over the Vistula, constructed in a modified Dutch-type truss system, contrary to Zieliński's usual practice and original idea of parabolic system. Unfortunately the bridge collapsed on 20$^{\text{th}}$/21st July 1884 at night during the so called St. John cyclical flood.

The theoretical length of each span was 88 m [27], and the clear width of the deck was ~8.69 m (28 feet and 6 inches). Such a significant width resulted from its possible future adaptation for two tracks, even though only one was laid. Each truss span was divided into 22 sections, 4 m wide. The span height was 9 m. Compared to the original Dutch system, two significant modifications were introduced: first of all, the transverse beams of the deck were attached to the lower chords of the trusses, not in the web, but to the upper flange of the chord box section. This change forced the modification of the structure of the truss posts, which were made as double-branch bars with batten plates and lacings. The structure schemes of the bridge over the Vistula river are presented in Figs. 4 and 5.

Regardless of the railway tracks, the bridge structure was adapted to carry road traffic, with a design axle load of ~7371 kg (450 poods) [21, 22]. Importantly, however, the deck arrangement did not allow for simultaneous road and rail traffic, so the movement of road vehicles was only possible between train runs. Additionally, pedestrian walkways were designed on both outer sides of trusses.

The foundation of the pillars was designed on caissons, 17.07 m (8 fathoms) below the lowest water level (the bridge over the Vistula was the only structure on the IDR in which caissons were actually used). The foundation of the abutments was designed with the use of piles [25].

7.2. Bridge on the Pilica

As already mentioned, most of the bridges built on the IDR were characterized by an unified structure. Some exceptions to these rules were made on the bridges over Czarna Nida and Pilica, where semi-parabolic trusses were used.

Particular attention should be paid to the bridge over the Pilica river, which consisted of three spans with a clear span of 53.35 m (25 fathoms) each. Each truss was divided into 15 sections with lengths (between the post axes) of 3.65 m. The height of the trusses, measured between the chord axes ranged from 6.355 m above the supports to 7.823 m in the middle of

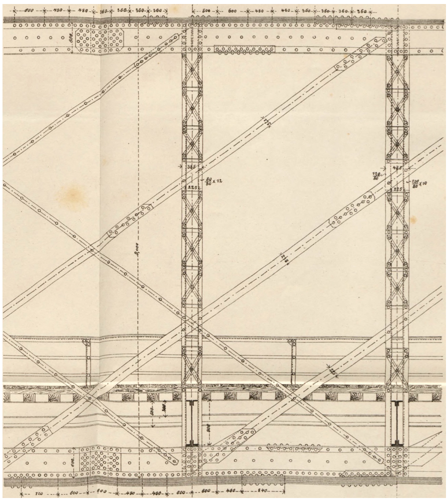

Fig. 4. Scheme of the truss of bridge over the Vistula river, compiled by S. Zieliński [26]

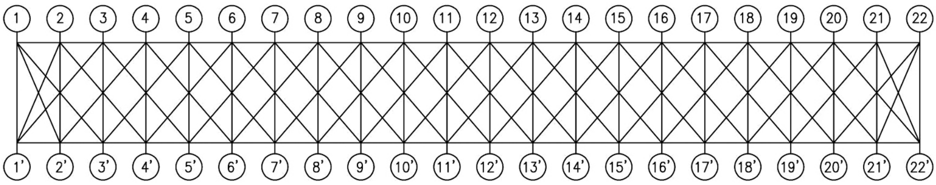

Fig. 5. Horizontal bracings of bridge on the Vistula, based on [19]

the span. As the span was constructed in a closed system (trusses braced at the level of the upper and lower chords), the height of the truss had to take into account the requirements of the vertical gauge, which was 5.547 m. The gauge width was set at 4.877 m.

The deck was designed for a single track, although, in accordance with [21, 22, 27], the abutments and pillars were widened to enable a double-track line in the future.

The diagram of the truss span of the Pilica bridge is presented in Fig. 6.

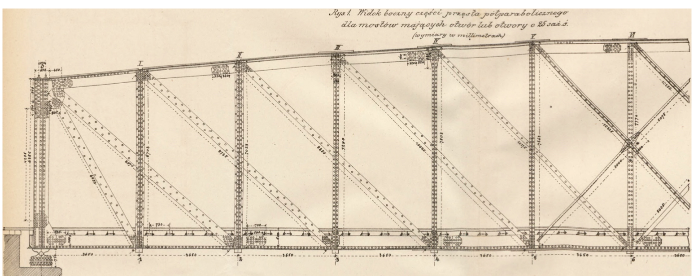

Fig. 6. Diagram of the semi-parabolic truss span of the Pilica bridge, compiled by S. Zieliński [26]

8. Operational issues

Routing typical Russian 1520 mm track was accompanied by laying narrow gauge working track and wooden temporary bridges, with allowed for traffic of building material, rails and build segments of permanent bridges [28, 29].

During IDR construction ministerial guidelines defined the scope and method of carrying out load and acceptance tests. I. e. for Vistula bridge these consisted of test runs and two-hour stops of trains consisting of three heavy, four-axle locomotives and five cars per track along each bridge span. On two-track bridges next test would extend to both tracks per span, then two spans simultaneously. The last test would take the train of three locomotives with tenders to run across at 32 km/h (30 versts per hour), 10.67 km/h (10 v/h) more than assumed normal speed of about 21.34 km/h (20 v/h) [22].

Maintenance and ongoing technical inspection were issues resolved differently than at present. These functions on various railways were duties of watchmen, who were kind of lineman hired for constant attention and control of the traffic, both train and cart. Bridge fire protection was based on watchmen doing their rounds after each train run, inspecting for fires started by sparks from wheels braking on rails, or hot coals ejected from steam engine's firebox. They were aided by barrels or vats of water, obligatory after cold season on wooden bridges longer than 10.67 m (5 fathoms) and combined with wooden gangways longer than 42.68 m (20 fathoms). Another role for watchmen was breaking ice floe and information of their superiors about every damage caused by it, particularly around weaker temporary bridges [31]. When a specialist ironworker was not hired, watchmen could have been trained and stationed on partially or fully metal bridges. They were equipped with tools for tightening bolt nuts, except for the ones on beams connecting the top and bottom chords and main beams, which was prohibited. From 1883 onward at least one ironworker was to be stationed for each 1.638 tons of bridge's metallic elements [32].

For performing his duties and better traffic safety watchmen had a set of signal flags for day time and a torch for night, he also carried signal petards [31]. Due to the strategic and economic importance of the Vistula bridge near Dęblin, special measures were undertaken on this particular crossing. Safety was handed to two two-person watchmen teams in two shift roster, one on each bridge end. They were informed about train departure from the nearest station by electric bells, and of closing distance by locomotive long whistles on the run-in. Train crews (train drivers and ober-conductor who was in charge) also had constant information about free tracks and open or closed crossings in the form of semaphores and green rotating dials or light signals at night. Familiarity of said signals applied also to station masters of Ivangorod-Passenger, Ivangorod-Freight and Garbatka stations.

Non train traffic (cart, pedestrians) was allowed between train runs and was dependent on schedule setting times of movement in each direction [33, 34].

9. Summary and conclusions

The beginning of railway construction in today's Poland dates back to the 1840s. In the following decades, the network was systematically developed. Despite war damage and economic and political changes, some structures erected at that time still function today. The construction of the IDR was an important step in the civilization and economic development of what is now southern and eastern Poland.

In 6 decades since Stephenson's pioneering activities, rail transport became crucial to both the economy and defense of the Kingdom of Poland as forward operating theatre of the Russian Empire.

Therefore, transport infrastructure (particulary rail and shipbuilding), including bridge construction became the most dynamically developing sectors in which modern solutions were implemented.

Technical progress was also followed by changes in legislation and the introduction of numerous documents regulating the process of designing and building railway bridges. These included ministerial guidelines, specifications, standards, and unified bridge catalogues. Therefore, also in formal terms, the construction of 19th century bridges set the directions that the bridge industry follows to this day.

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Wybrane problemy projektowania i wykonawstwa XIX wiecznych mostów kolejowych na przykładzie mostów Drogi Żelaznej Iwangorodzko–Dąbrowskiej

Słowa kluczowe: XIX wieczny most, kolej, konstrukcja stalowa, projektowanie konstrukcyjne, wiadukt

Streszczenie:

Droga Żelazna Iwangorodzko–Dąbrowska była najdłuższą linią kolejową w Królestwie Polskim w zaborze rosyjskim. Rozpoczynała bieg w Dęblinie (ówczesnym Iwangorodzie, twierdzy strzegącej przejścia kolejowego przez Wisłę), skąd wychodziła na Radom i Kielce do Dąbrowy Górniczej, gdzie odnogami łączyła się z lokalnymi kopalniami węgla Zagłębia Dąbrowskiego oraz kolejami zaborów austriackiego i niemieckiego. Natomiast powtarzając bieg rzeki Kamiennej, odnogami ze Skarżyska Kamiennej (ówczesnego Bzina) biegła na Ostrowiec oraz na Koluszki – stację Drogi Żelaznej Warszawsko-Wiedeńskiej, obsługując liczne huty i inne zakłady przemysłu metalurgicznego. Budowa tej linii przypadała na okres następujący bezpośrednio po głośnej katastrofie kukujewskiej w Rosji (1882), której bezpośrednią przyczyną był niewłaściwy dobór przekroju przepustu. Następstwem katastrofy było znaczne zaostrzenie przepisów dotyczących projektowania hydrologicznego mostów i przepustów. Obiekty mostowe w ciągu linii kolei Iwangorod-Dąbrowa były już projektowane w oparciu o nowe uregulowania, skutkiem czego linia wyróżnia się wysokim współczynnikiem długości światła otworów mostów na jednostkę długości trasy, wynoszącym 5,6 m/km (2,8 sążni na wiorstę).

Zmiany przepisów miały charakter stopniowy i zostały zapoczątkowane przez wprowadzenie okólnika ministerialnego w dniu 12 października 1882 roku. Wskazano w nim, że światło mostów i przepustów powinno być projektowane na przepływ odpowiadający 3 godzinnym opadom deszczu, w którym podczas 1 godziny pojawia się warstwa wody o wysokości 3,81 cm (1,5 cala). Oznacza to, że na każde 1,138 km^2 (1 wiorstę^2) powierzchni zlewni przypada 9,72 m^3 (1,25 sążnia^3) wody na sekundę. Okres budowy linii Iwangorodzko–Dąbrowskiej obejmuje również zmianę przepisów i wytycznych dotyczących przyjmowania schematów obciążeń eksploatacyjnych. W głównej mierze wynikało to z wprowadzenia do eksploatacji ciężkich czteroosiowych parowozów. W wytycznych Ministerstwa Komunikacji z dnia 6 czerwca 1881 roku zalecono, aby do wyznaczania sił wewnętrznych przyjmować siły skupione zamiast dotychczas obowiązujących obciążeń równomiernie rozłożonych. Układ tych siłskupionych miałodwzorowywać obciążenie pociągiem złożonym z trzech parowozów z tendrami oraz szeregu wagonów. Okólnik z 1882 roku określał ponadto zasady uwzględniania obciążenia wiatrem w projektowaniu mostów kolejowych. Już wtedy obowiązkowe było rozróżnienie dwóch sytuacji obliczeniowych, a mianowicie przypadku oddziaływania wiatru na przęsło nieobciążone i obciążone taborem kolejowym. W kontekście obciążenia wiatrem przepisy ministerialne podawały ponadto zasady projektowania pasów kratownic, stanowiących jednocześnie pasy skratowania poziomego. W Królestwie Polskim warunki techniczne projektowania i wykonawstwa robót były formalnie wydawane przez ministerstwo niezależnie dla każdej budowanej trasy, choć poszczególne dokumenty cechowało wiele wspólnych, powtarzalnych rozwiązań. Zgodnie z warunkami technicznymi wydanymi dla Drogi Żelaznej Iwangorodzko–Dąbrowskiej przęsła należało budować pod pojedynczy tor, choć jednocześnie wymagano, aby szerokość podpór była większa, to jest wystarczająca do ewentualnej przyszłej budowy mostu równoległego. Jako materiałkonstrukcyjny wskazywano kamień, cegłę lub stal. Zastosowanie drewna jako materiału konstrukcyjnego dopuszczano w obiektach tymczasowych oraz obiektach stałych o rozpiętości nie przekraczającej 2,13 m (1 sążeń). Mosty dłuższe niż 14,94 m (7 sążni) należało budować na prostych odcinkach trasy. Na obiektach o długości większej niż 4,27 m (2 sążnie) wymagano zastosowania balustrad.

Na żądanie Ministerstwa Komunikacji obiekty wyposażano w zapory po obydwu stronach wjazdu. Kwestia wyboru sposobu posadowienia była przedstawiona dosyć ogólnikowo. Wymagano jedynie, aby mosty na Wiśle i Pilicy posadowić na kesonach. Zasypka przyczółków powinna być z kamienia, piasku albo innego suchego i niegliniastego gruntu. Z uwagi na fakt, że warunki techniczne były wydawane niezależnie dla każdej trasy, mogły one zawierać zapisy odnoszące się do konkretnych mostów, w ściśle określonych lokalizacjach. I tak na przykład wymagano, aby most na Wiśle pod Iwangorodem, oprócz ruchu kolejowego, był przystosowany do ruchu drogowego. Wskazano przy tym wymagane obciążenia tymi pojazdami, które należało uwzględnić podczas projektowania. W okresie budowy Drogi Żelaznej Iwangorodzko–Dąbrowskiej wytyczne ministerialne określały zakres i sposób przeprowadzania badań odbiorczych oraz próbnego obciążenia. Test zwykle polegał na próbnych przejazdach oraz dwugodzinnych postojach składów kolejowych w postaci trzech ciężkich, czteroosiowych lokomotyw i pięciu wagonów na tor na długości całego przęsła. Na mostach dwutorowych następnie testowano przęsło na obu torach równolegle. Następnie testowano dwa przęsła równocześnie. Ostatnią próbą był przejazd składu trzech lokomotyw z tendrami przez most z prędkością 32 km/h (30 wiorst/h).

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