DOI: 10.36137/2004E

INSTYTUT KOLEJNICTWA

Railway Reports – Issue 200 (September – December 2023) ISSN 0552-2145 (druk) ISSN 2544-9451 (on-line)

Key Issues Related to Permanent Way in the Work of Professor Henryk Bałuch

Andrzej MASSEL[1]

Permanent Way is a term covering the design, construction and maintenance of railroads, including both the structure and geometric layout of the track. Under the current classification, permanent way issues fall within the field of engineering sciences, in the discipline "civil engineering, surveying and transport" [34]. This discipline combines the design, construction and operation of railways and includes issues related to earthworks engineering, railway superstructure, geometric layout of tracks and their connections, as well as any track-related facilities like bridges, flyovers and tunnels. On the other hand, a subject of research under the same discipline is the problems of rail traffic and transport organisation.

Permanent way fundamentals were outlined in Polish literature soon after Poland regained its independence, in outstanding monographs by Professors Aleksander Wasiutyński of the Warsaw University of Technology and Karol Wątorek of the Lviv University of Technology. One must also mention the remarkable theoretical papers that contributed greatly to the development of global science. Of particular importance were, above all, the publications by Professor M.T. Huber.

After the Second World War, many important works were compiled in Poland, including those by B. Hummel, R. Szajer, A. Rubczak and T. Basiewicz. It is also essential not to overlook the comprehensive monograph on railroads edited by J. Sysak [35]. Vital publications were also prepared by the employees of the Central Research and Development Centre of Railway Technology (COBIRTK), later renamed the Railway Scientific and Technical Centre (CNTK), including by K. Towpik (especially on the technology of railway works and contactless track), A. Oczykowski (superstructure and fastening systems), E. Skrzyński (railway track bed and ballast materials), and S. Zimnoch (construction of level crossings).

However, the greatest contribution to the development of the theoretical foundations of permanent way, as well as to practical methods and tools to improve the processes of design, construction and maintenance of railroads, was Professor H. Bałuch's works. This article is devoted to the most important issues related to permanent way, in light of the Professor's publications, with particular emphasis on his articles in Problemy Kolejnictwa (Railway Reports).

Professor Henryk Bałuch

Henryk Bałuch was born on 24 May 1932 in Lwów (now Lviv). He went through a lengthy career path, successively obtaining the following diplomas: journeyman locksmith and turner at the Vocational School in Przemyśl, technician at the Building and Road Engineering High School in Wrocław, communications engineer at the Warsaw University of Technology and master's degree in civil engineering at the Krakow University of Technology. His later professional achievements were greatly influenced by his work in the PKP railroad maintenance units (PKP Railroad Branch in Rzeszów), first as a track supervisor and then as an engineer in charge of work.

In 1963, Henryk Bałuch, master of science at the time, was officially transferred to the then Central Research and Development Centre of Railway Technology (COBIRTK) in Warsaw. In the early years of his work at COBIRTK, he dealt with the issue of adapting the railway superstructure to high travelling speeds and heavy traffic. This was the subject of his doctoral thesis, which he defended at Poznań University of Technology in 1966. In the same year, H. Bałuch became head of COBIRTK's Department of Railroads. In heading this Department, he contributed to a significant improvement in the quality of its work and

[1] Ph.D. Eng.; Railway Research Institute, Director; e-mail: amassel@ikolej.pl.

to the implementation of new research methods. He actively participated in this research, concentrating at the time on the problem of optimising railway turnout geometric layouts [9]. The result of his research was the award of a postdoctoral degree at the Cracow University of Technology in 1969. For 12 years, from 1970 to 1982, Henryk Bałuch was the COBIRTK Deputy Director for Scientific and Research Affairs. From 1982 he was the director of that unit. Notably, COBIRTK, eventually transformed into the Science and Technology Railway Centre in 1987, was one of Europe's largest railway research units [30, 33].

One cannot overlook the international activities of Professor Bałuch, in particular, his active participation in numerous Expert Committees of the UIC Office of Research and Testing (ORE) and later of the European Rail Research Institute (ERRI), especially Committees D117, D161, D187 and D202. The Professor's many years of activity in these international specialist teams made it possible to draw on the experience of other railways, as well as to undertake new research topics.

Just as important as Henryk Bałuch's academic degrees and titles, as well as unquestionable research achievements, was his personality, his being a man of great erudition and culture of language, eager to pass on his knowledge to his colleagues. At this point, it is worth referring to A. Gołaszewski's very moving memoir about the Professor [32].

Publications by Henryk Bałuch in Problemy Kolejnictwa (Railway Reports)

One of the first publications by H. Bałuch was a 1965 article in Problemy Kolejnictwa (Railway Reports) [20]. It was devoted to improving the conditions of rolling stock movement on curves. It also analysed the effect of lateral forces on the destruction of wooden sleepers. Notably, a reference to this subject was an article by M. Bałuch and H. Bałuch in 2000, presenting operational methods for extending rail replacement cycles on small radius curves [27]. H. Bałuch's 1960s publications also included an article in Problemy Kolejnictwa (Railway Reports) in 1967 on methods of determining the characteristics of the railway bed [12].

H. Bałuch devoted many papers to determining the optimal construction of the superstructure and its maintenance system, taking into account the Polish railway conditions. Particularly extensive coverage of the issues was given in an article contained in a 1971 volume of Problemy Kolejnictwa [Railway Reports], released on the 20th anniversary of the then Central Research and Development Centre of Railway Technology [4]. Bałuch's next important article in this thematic area, devoted to assessing the railway superstructure under the conditions of the ongoing changes in transport technology, was written in 1989 [7]. It outlined the directions for the development of the superstructure with particular reference to the weakest areas of the track: turnouts and sections located on small-radius curves. With regard to turnouts, it recommended the widespread use of forged or manganese steel crossings, the introduction of heat treatment of crossings and switch rails, and the implementation of creep-resistant locking devices. The proper adjustment of the cant in the track to the speed of passenger and freight trains, the laying of rails made of higher quality steel and the use of rail lubrication were recommended to improve the track condition on small radius curves. The article [7] also made important recommendations on diagnostics and maintenance, including the recommendation to plan superstructure repairs based on diagnostics with decision support from expert systems. In terms of repair technology, the need for wider implementation of rail grinding was identified.

One of the most important scientific problems undertaken by H. Bałuch was the reliability of the railway superstructure, in particular, the methods of determining the durability of its components. One 1971 issue of Problemy Kolejnictwa (Railway Reports) was entirely devoted to the reliability of railway transport. An article by T. Basiewicz and H. Bałuch, defining criteria for superstructure reliability, among other things, occupied a prominent place in that issue [29]. Characteristics of the structural reliability of the basic superstructure components (rail damage intensity, sleeper reliability, turnout life parameters) were also presented. A more detailed approach was taken in a 1984 article in which H. Bałuch presented research results on the influence of rail spacers on the durability of rail fastenings to sleepers [21]. The vibration analysis considered both single- and double-mass models of rail fastenings to sleepers and slabs. The effect of rail spacers as anti-creep elements was also analysed.

Research on the durability of rails had a prominent place in H. Bałuch's articles [10]. A co-authored article from 2010 deals with the problem of predicting rail cracks [25]. An analysis of rail cracks between 2006 and 2010 made it possible to assess the risks to the railway superstructure. This analysis showed that the majority of rail cracks occurred during periods of low temperatures. At the time, cracks in termite welds were the most common. It is worth mentioning that the number of rail cracks per 1 kilometre was considered as a criterion for their continuous replacement in light of the studies conducted at the CNTK at that time. The article characterised the forecasting methods, presenting the possible errors.

The reliability of the track superstructure on railway lines is highly dependent on workmanship quality. A 2014 co-authored article presents a model of process reliability and isolates the components of workmanship quality, that is, accuracy and efficiency [28]. The article describes specific examples of faulty workmanship and proposals for measures to eliminate it. Appropriate checklists for the most important substructure and superstructure work were proposed.

Various quality assessments are useful tools for maintaining the superstructure and reducing life cycle costs. In a 2015 article, H. Bałuch discussed the different methods of determining quality indicators and presented four methods of synthetic assessment of superstructure condition, as well as their objectives [13]. The simplest of these methods uses a synthetic indicator of track condition based on the standard deviations of vertical and horizontal irregularities, as well as track twist and width. The second method uses the same indicator but takes traffic load into account. The third method assesses the rails' expended service life, as well as the age of the sleepers. The last method examines the extent to which permissible deviations are exceeded [13].

Another one of H. Bałuch's articles of great scientific value was included in a 2017 volume of Problemy Kolejnictwa (Railway Reports) [1] and was devoted to the determinants of railway superstructure replacements. In it, Bałuch draws attention to the desirability of superstructure replacements. The objectives of the repairs may be to ensure adequate durability and safety, enable trains to travel at the required speed, reduce operating costs, and improve smooth running. To attain these goals, it is necessary to achieve better workmanship accuracy, expressed in the standard deviation value of vertical track irregularities of the order of 0.6 mm.

Much of Professor Bałuch's work concerned the design of track and track connection geometric layouts. These culminated in two significant monographs: one on optimising track layouts [8] and the other on the design of track connections [19]. Geometric layout issues were the subject of articles in Problemy Kolejnictwa (Railway Reports), which analysed track layouts on newly designed and reconstructed railway lines. Here, mention should be made of a 1982 publication on the design of transition curves on modernised railway lines [5]. A co-authored 2012 article refers to errors in the design of track layouts and proposes breaking them down into seven types. Attention was given to their origins as well. Some of the errors were due to an inadequate design that did not take into account the situation on the ground; others arose at the execution stage as a result of violations of well-known principles and good practices [26].

The development of computer techniques in the 1980s and 1990s made it possible to develop advisory systems for decision support in various areas of the economy, including railways. Many such systems have found application in railway maintenance. The concept of their use was created by H. Bałuch, with their basic principles presented in numerous Problemy Kolejnictwa (Railway Reports) articles. The first of these publications was written in 1990 [17]. Notably, in Polish, these "expert systems" were initially referred to as "systemy ekspertowe", with this name eventually superseded by "systemy eksperckie". In decision support systems, algorithmic modules and heuristic rules (using a knowledge base) form the basis for conclusions [16]. The most important systems included [3, 14–17, 22]:

- UNIP (Pressure and Speed Determination),
- DONG (Overhaul Decisions),
- DOSZ (Rail Grinding Decisions),
- JAKON (system for assessing superstructure work quality),
- SOHRON (system for prioritising superstructure work according to track degradation characteristics and effects),
- SONIT (system for assessing track irregularities),
- DIMO (support system for pre-modernisation diagnostics).

With the separation of rail infrastructure management from freight operations, it became important to address the issue of how to determine the costs of infrastructure access depending on operating conditions, including traffic structure (passenger, freight), travel speed and axle load. This topic was the subject of a 2001 article by H. Bałuch [18].

In recent years, risk assessment methods have become particularly important in the operation of technical equipment and systems. This also applies to risks in the operation of rail superstructures. It should be mentioned here that the Railway Safety Directive establishes harmonised methods for monitoring, conformity assessment, supervision and risk evaluation and assessment, which apply to the actors of the European Union railway system and the national safety authorities [31]. In a 2007 article, H. Bałuch noted that addressing risk issues concerning railway superstructures is aimed at improving driving safety and the safety of workers employed in superstructure maintenance, repair and upgrade work [11]. This can be achieved by significantly increasing the resources devoted to superstructure maintenance. Certain risk estimation methods, appropriately targeted research work and accident-specific training can also help in this effort [27].

In risk assessment, hazard identification is crucial. An extensive 2013 article by H. Bałuch [23] is devoted to studying and preventing hazards in railway superstructures. One particular type of hazard is that leading to derailments. Apart from catastrophic

hazards that threaten derailments, such as track buckling, many other hazards in the railway superstructure lead to losses, e.g. increased life cycle costs and disruptions to normal operations. In Bałuch's opinion, derailments should be investigated with the initial assumption that their causes may be a combination of events and a coincidence of damage and defects. The paper presents the required stages of work leading to reducing railway road hazards and a proposed typology of damage and defects in the railway superstructure. Further, the article includes a model of the hierarchy of repairs to the railway superstructure to be used where there are no sufficient resources to address all the defects. The article's final section includes a description of the development of superstructure damage and defects, the importance of visual diagnosis and the role of skills improvement [23].

The quality of track system design, as well as that of construction work and superstructure maintenance, is significantly affected by the qualifications of engineers. The education of engineers handling railway infrastructure was the topic of an article by H. Bałuch published in a 2012 volume of Problemy Kolejnictwa (Railway Reports) [6]. The author presented engineering performance as a test of the level of education. In this approach, education quality is construed as the ability to perform a specific profession. It is closely linked to continuous learning throughout one's professional life. Universities should develop this key combination of the above skills.

What emerges from H. Bałuch's articles is a farsightedness and a reference to problems that would soon prove to have a decisive impact on the functioning of societies and economies. These include progressive climate change and the gradual depletion of non-renewable energy sources. The impact of these changes on railway construction was the subject of Professor Bałuch's final publication in Problemy Kolejnictwa (Railway Reports), released in the summer of 2019 [24].

Summary

The issues taken up by Professor Henryk Bałuch in Problemy Kolejnictwa (Railway Reports) publications between 1965 and 2019 make evident the broad spectrum of his scientific interests. He investigated issues that were critical for operating practice, including railway track geometric and kinematic assessment, railway superstructure hazards, track geometric layouts and deformations, optimising geometric layouts of turnouts designed for heavy traffic and high-speed trains, the influence of workmanship quality on the life of the railway superstructure, advisory systems for superstructure repairs, permissible deviations in the superstructure, assessment of rail corrugations, and neural networks, applied as a tool for solving railway road problems.

The contributions of H. Bałuch were vital for the Polish railway industry. Through his research, he made it possible to increase the durability of railway superstructures. He unambiguously pointed out the desirability of choosing heavy track superstructures for Poland's core railway lines and the need to have them produced by Polish metallurgy plants and introduced to Polish railways (S60 rails, elastic rail fastening system, concrete sleepers, railway turnouts on concrete switch sleepers). No less significant are Professor Bałuch's contributions to the development of railway diagnostics, the optimisation of track geometric layouts, the improvement of the quality of superstructure workmanship and the training of the Polish railway technical staff [32].

References

1. Bałuch H.: *Determinanty wymian nawierzchni kolejowej* [Determinants of Replacing Railway Superstructure], Problemy Kolejnictwa, 2017, z. 175.
2. Bałuch H.: *Jakość robót nawierzchniowych i metody jej oceny* [Quality of Superstructure Works and their Estimation Methods], Problemy Kolejnictwa, 1998, z. 128.
3. Bałuch H.: *Koncepcja systemów doradczych w diagnostyce nawierzchni kolejowej i podtorza*, [Idea of decision support systems in diagnosis of permanent way and subgrade] Problemy Kolejnictwa, 1996, z. 121.
4. Bałuch H.: *Kierunki doskonalenia konstrukcji oraz systemu utrzymania nawierzchni PKP* [Outlines of improvement in permanent way construction and maintenance system on the PKP] Problemy Kolejnictwa, 1971, z. 54.
5. Bałuch H.: *Krzywe przejściowe w modernizacji linii kolejowych PKP* [Transition curves in the modernization of PKP railway lines], Problemy Kolejnictwa, 1982, z. 94.
6. Bałuch H.: *Kształcenie inżynierów dla potrzeb infrastruktury kolejowej* [Engineering Education for the Needs of Railway Infrastructure], Problemy Kolejnictwa, 2012, z. 155.
7. Bałuch H.: *Ocena konstrukcji i utrzymania nawierzchni kolejowej w świetle zarysowujących się zmian w technologii przewozów* [Evaluation of track structure in relationto some change in transport techniques], Problemy Kolejnictwa, 1989, z. 105.
8. Bałuch H.: *Optymalizacja układów geometrycznych toru* [Optimization of Track Geometric systems], Wydawnictwa Komunikacji i Łączności, Warszawa, 1983.

9. Bałuch H.: *Optymalizacja układu geometrycznego rozjazdów przeznaczonych do dużego natężenia przewozów i dużych szybkości pociągów*, Problemy Kolejnictwa, 1968, z. 44.
10. Bałuch H.: *Problemy monitorowania szyn i ich miejsce w systemie GIS-RAIL* [Rail monitoring problems and their place in the GIS-RAIL system], Problemy Kolejnictwa, 2005, z. 140.
11. Bałuch H.: *Ryzyko w eksploatacji nawierzchni kolejowej* [The risk in operation of railway track], Problemy Kolejnictwa, 2007, z. 145.
12. Bałuch H.: *Sposoby wyznaczania charakterystyk podłoża kolejowego* [Methods of determining the characteristics of the railway subgrade], Problemy Kolejnictwa, 1967, nr 39.
13. Bałuch H.: *Syntetyczne metody oceny nawierzchni kolejowej* [Synthetic Methods for the Evaluation], Problemy Kolejnictwa, 2015, z. 166.
14. Bałuch H.: *System doradczy w ocenie celowości szlifowania szyn* [The expert system in the evaluation of usefulnes of rail grinding], Problemy Kolejnictwa, 1995, z. 118.
15. Bałuch H.: *System geometryczno-kinematycznej oceny toru kolejowego* [System for geometrical and kinematical evaluation of the state of railway tracks], Problemy Kolejnictwa, 2002, z. 136.
16. Bałuch H.: *Systemy eksperckie w diagnostyce nawierzchni kolejowej* [The expert systems in the railway track diagnostic], Problemy Kolejnictwa, 1993, z. 114.
17. Bałuch H.: *Systemy ekspertowe i koncepcja ich zastosowania w problematyce nawierzchni kolejowej* [Prossibility of the application the expert systems in railway track problems], Problemy Kolejnictwa, 1990, z. 107.
18. Bałuch H.: *Techniczne podstawy określenia wpływu ruchu pasażerskiego i towarowego na koszty utrzymania nawierzchni kolejowej* [Technical bases of passenger and freight traffic influence on the railway substructure maintenance costs], Problemy Kolejnictwa, 2001, z. 134.
19. Bałuch H.: *Układy geometryczne połączeń torów* [Geometric systems of track connections], Wydawnictwa Komunikacji i Łączności, Warszawa, 1989.
20. Bałuch H.: *Wpływ sił bocznych w torze na niszczenie podkładów drewnianych* [The influence of lateral forces in the track on the destruction of wooden sleepers], Problemy Kolejnictwa, 1965, z. 32.
21. Bałuch H.: *Wpływ przekładek podszynowych na trwałość przytwierdzeń szyn do podkładów* [Influence of rail pads upon rail fastening systems service life], Problemy Kolejnictwa, 1984, z. 98.
22. Bałuch H.: *Wspomaganie decyzji w drogach kolejowych* [Decision support in railways], Kolejowa Oficyna Wydawnicza, Warszawa, 1994.
23. Bałuch H.: *Zagrożenia w nawierzchni kolejowej – badania i przeciwdziałanie* [Dangers in Railway Permanent Way – Research and Remedies], Problemy Kolejnictwa, 2013, z. 158.
24. Bałuch H.: *Zmiany klimatu i zużycie energii – przykłady związków z budową kolei* [Climate Change and Energy Consumption – Examples Associated with Railway Construction], Problemy Kolejnictwa, 2019, z. 183.
25. Bałuch H., Bałuch J.: *Prognozowanie pęknięć szyn* [Forecasting Rail Cracks], Problemy Kolejnictwa, 2010, z. 151.
26. Bałuch H., Bałuch M.: *Typologia błędów w kształtowaniu układów torowych* [Typology of Mistakes in Planning the Track Outlay], Problemy Kolejnictwa, 2012, z. 156.
27. Bałuch M., Bałuch H.: *Eksploatacyjne metody wydłużenia cykli wymian szyn w łukach o małych promieniach* [Operation possibilities of the life cycle extension of the rail renewal in curves with small radius], Problemy Kolejnictwa, 2000, z. 132.
28. Bałuch M., Bałuch H.: *Kształtowanie niezawodności nawierzchni w toku modernizacji linii kolejowych* [Shaping the Reliability of the Permanent Way During the Modernization of Railway Line], Problemy Kolejnictwa, 2014, z. 162.
29. Basiewicz T., Bałuch H.: *Niezawodność nawierzchni kolejowej* [The permanent way's reliability], Problemy Kolejnictwa, 1971, z. 51.
30. Bogdaniuk B.: *Prof. dr hab. inż. Henryk Bałuch – zarys działalności* [Prof. Ph.D. engineer Henryk Bałuch – outline of his activities], Technika Transportu Szynowego, 2002, nr 11–12, s. 27–28.
31. Dyrektywa Parlamentu Europejskiego i Rady (UE) 2016/798 z dnia 11 maja 2016 r. w sprawie bezpieczeństwa kolei, OJ L 138, 26.5.2016.
32. Gołaszewski A.: *Wspomnienie o Profesorze Henryku Bałuchu* [In Remembrance of Professor Henryk Bałuch], Problemy Kolejnictwa, 2020, z. 187.
33. Massel A.: *Sesja Naukowa z okazji 45-lecia pracy naukowej i 70-lecia urodzin Profesora Henryka Bałucha* [Scientific Session on the occasion of the 45th anniversary of scientific work and the 70th anniversary of the birth of Professor Henryk Bałuch], Technika Transportu Szynowego, 2002, nr 11–12, s. 26–27.
34. Rozporządzenie Ministra Edukacji i Nauki z dnia 11 października 2022 r. w sprawie dziedzin nauki i dyscyplin naukowych oraz dyscyplin artystycznych (Dz.U. z 2022 r. poz. 2022).
35. Sysak J. (red.): *Drogi kolejowe* [Railway roads], Państwowe Wydawnictwo Naukowe, Warszawa, 1982.