ADVANTAGES OF BALLASTLESS TRACK DESIGN FOR LARGE TRANSPORT OBJECTS

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ABSTRACT

The article assesses the possibility of using a ballastless (or slab) track design (BTD) in implementation of large transport facilities in the city. BTD is the only alternative to a traditional track on ballast. Such an option has a number of advantages, but at the same time, certain shortcomings that restrain its mass application today. Based on foreign experience and comparison of two designs (track on ballast and BTD), taking into account costs for repair and current maintenance, the authors offer their understanding of economic arguments and benefits derived from operation of the ballastless track.

Keywords: *railway transport, track superstructure, ballastless structure, high-speed traffic, costs, payback, economic effect.*

Background. *For more than a decade the experts of transport construction have been facing the issue of the most rational design of track superstructure that would meet all the necessary conditions, namely: constantly increasing speeds of movement and the load on the axis. Even at the beginning of 20th century, foreign and domestic scientists tried to obtain a stable track design, equally applicable to both industrial and civil traffic. For the first time track with a solid reinforced concrete base was offered and implemented in various variants in 1909 by our compatriot, Russian engineer N. E. Dolgov. The main idea was to create an efficient design without sleepers and ballast. Laid on the track designs of Dolgov on Pridneprovskaya Railway served from 20 to 40 years. In 1924, the Japanese national railways began to build a track with wooden supports-liners, submerged in a monolithic reinforced concrete base. In 1926–1929, reinforced concrete undertrack bases in the form of blocks were laid on the Per-Marquette road in the USA [1].*

Objective. *The objective of the authors is to consider advantages of ballastless track designs.*

Methods. *The authors use general scientific methods, comparative analysis, economic assessment.*

Results. *To date, the leading countries in this area are Germany, Austria and Japan. There are dozens of variants of ballastless track designs (BTD) and all of them are included in serial production. In the overwhelming majority of their studies, foreign experts do rely on a comparison of two track designs (Table 1).*

When comparing it is natural to conclude that the main criterion in favor of choosing BTD is stability of the geometry of track and the low cost of current maintenance, which is precisely an advantage over the track design on ballast. A fair number of works [5, 6] on this topic allow us to formulate from an economic point of view a certain general concept regarding construction and operation of BTD: high initial investment for construction is paid for by reducing the cost of current maintenance.

Let's consider the foreign experience in construction of new railway lines intended for high-speed passenger traffic (Table 2).

Separately it is worth noting two BTD designs, which are the most widely spread around the world. Table 3 presents the designs of Bögl FFB and Rheda 2000, as well as the polygons for their laying. The popularity of these types is explained by the fact that they have a satisfied long operational experience – in 1972 the first such structure was laid at the station of Reda in Germany [3].

As can be seen from Table 2, to date, the ballastless track is mainly used in the east, in China and Japan, whereas in Europe the traditional ballast track remains the basic design of track superstructure. This can be explained by the fact that one of the rational spheres of application of the ballastless track is the track on overhead road. For example, some lines of Japanese high-speed railways pass through overhead roads in almost 90 % of cases. Often the track on the overhead road is due to the presence of a complex terrain, but it is also quite relevant when passing a railway line to places with already established social infrastructure [4].

We can say that the ballastless track is quite an «urban structure» within the transport infrastructure of the megalopolis. Such a term is possible due to the main positive criteria of the BTD in conditions of intra-urban traffic organization. These include: low construction height of the structure, the ability to pass vehicles, full mechanization and automation during

Table 1

Comparison of track designs

Feature of a design	Track on ballast	Ballastless track
Low capital costs for construction	+	–
Low costs for current maintenance	–	+
Possibility to adjust the geometry of track gauge	+	–
Reconstruction of track after an emergency	+	–
Stability of continous welded track	–	+
Low maintenance	–	+
Noise and vibration damping	+	–
Convenience of use on artificial structures and in cramped conditions (bridges, tunnels, overhead roads)	–	+

Table 2

Comparative analysis of main parameters of implementation of HSR projects in the world [2, p. 31]

Project	Completion of construction	Length, km	Number of tracks	Track type	Average speed, km/h
HS1 (Great Britain)	2007	108	2	Mixed	225–300
HSL Zuid (the Netherlands)	2009	125	2	Ballastless	300
LGV Est (France)	2007	300	2	Ballast	320
Cologne–Frankfurt (Germany)	2004	177	2	Ballastless	300
Rome–Naples (Italy)	2009	205	2	Ballast	300
Madrid–Barcelona (Spain)	2008	619	2	Ballast	300
Kyushu–Sinkansen (Japan)	2004	127	2	Ballastless	260
Taipei–Kaosiung (Taiwan)	2007	344	2	Ballastless	300
Beijing–Shanghai (PRC)	2011	1318	2	91 % – ballast; 9 % – ballastless	300 and 250
Seoul–Taegu (South Korea)	2007	330	2	Mainly ballastless	300

Table 3

Polygon for laying BTD Bögl FFB and Rheda 2000

Type of BTD	Manufacturing country	Name of track section
B gl FFB	Germany	Germany. Karlsruhe–Basel, the Katzenberg tunnel
		Germany. Nuremberg–Ingolstadt
		Germany. Nuremberg–Ebensfeld–Erfurt–Leipzig / Halle
		China. Beijing–Tianjin
Rheda 2000	Germany	Germany. Mainz–Mannheim. Upgrading the Alter Minster tunnel
		India. Udhampur–Srinagar–Baramulla
		China. Experimental section of the Su-Yu line: Suining–Chongqing

Table 4

The resulting economic effect when comparing options

№	Scope of track operation	Effect when comparing track design according to option I and II, thousand rubles
1	Mid-life repair (C)	216000
2	Routine-preventive (B)	108000
3	Current maintenance	10800

construction and reduction of frequency of repair work.

Speaking about transport in the city, it is necessary to highlight the problems of current maintenance, taking place in a dense urban environment, and the problem of the frequency of repairs, as well as the provision of repair intervals. If we cite example of Moscow, then we should mention a large railway facility which is Moscow Central Circle (MCC). Initially, in 1908, it was designed for a mixed (including urban passenger) movement. Until recently (before the beginning of reconstruction in 2012), there was no contact network on the circle and all transportations were carried out by means of diesel locomotives. The design of the track selected during reconstruction was also traditional. This is due to huge accumulated experience and the availability of a sufficiently extensive material base, which makes the track on ballast simple and affordable.

But going back to foreign experience and the basic concept of BTD, one should consider the main advantages, due to which the ballastless track in future can take a dominant position in construction of large transport facilities. One of such advantages can be attributed to the effect achieved in the field of operation. The scope of operation includes repair of the track and its current maintenance. Table 4 shows the effects (calculated for track superstructure and substructure), depending on repair and the current maintenance of MCC line, 54 km in length, where the traditional track on ballast and BTD options I and II, respectively.

As can be seen from Table 4, the additional one-time costs for repair and current maintenance of track of option I (BTD) as compared to option II (traditional on ballast) give a certain economic effect. Although, of course, there are certain risks in construction and operation of BTD due to the poorly understood scheme in Moscow conditions.

The payback of railway transport infrastructure is due to the volume of cargo transported and the number of passengers. Hence it follows that the more is passenger flow, the greater is the revenue component. Unlike the high-speed communication lines planned for construction (where the passenger flow will be unevenly distributed over sections), the

lines of intraurban traffic will undoubtedly have a more even and more congested traffic. For comparison, it is possible to consider the annual passenger flows of large transport objects. So, the optimistically forecasted total passenger flow on Moscow–Kazan HSR (taking into account all stop points) by 2020 should reach 10,5 million people per year. The annual passenger flow of Moscow metro for 2015 was 2384,5 million people, and the forecasted for 2017 passenger flow of MCC should be between 75 and 300 million people. Consequently, the payback of an intracity transport facility will be carried out within a reasonably acceptable timeframe, and the transportation itself will be more profitable [2, 7, 8].

Conclusion. *Perhaps in the future, during reconstruction of the MCC or implementation of similar projects, one should think about the application of the ballastless track design. It may well become the main design of track superstructure in the conditions of a metropolis, taking into account its efficiency in the process of operation.*

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