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Volume 2

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SINARG 2023

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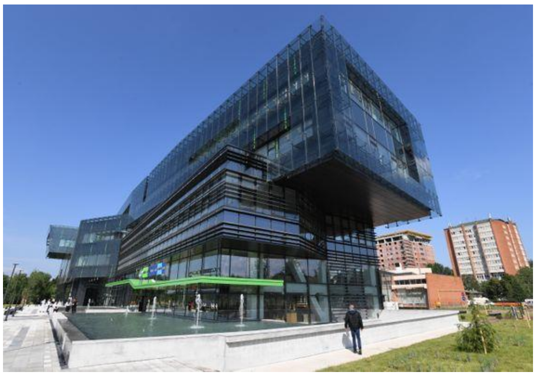

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PREFACE

The primary goal of the SINARG 2023 conference is to present contemporary achievements in the scientific and practical aspects of architecture and civil engineering. The organizers of the conference aimed to facilitate the participation of both national and international professionals in theoretical and experimental research related to the processes of design, project management, construction, and building maintenance within the construction industry.

Simultaneously, this scientific conference serves as a platform for exchanging experiences and information regarding innovations and advancements in planning, design, new materials, and construction and reconstruction technologies within the fields of architecture and civil engineering.

Therefore, this conference should serve as a forum where experts from civil engineering, architecture, and other related fields have the opportunity to present the results of their research. In that context, conference topics have been carefully selected to provide focus on current issues in the field and encourage productive discussion bringing fresh and original insights and concepts to the forefront.

More than 180 paper proposals have been submitted to the conference. A single-blind review process was used to assess the full papers. The reviewers are esteemed scientists holding PhD degrees in the same field as the paper's topic. There are more than 70 reviewers from ten countries who have significantly contributed to the scientific quality of the conference, and their names are printed in the proceedings.

A total of 142 full papers have been accepted for publication. Some of the papers have been selected for publication in our journals, with nineteen papers in Facta Universitatis: Architecture and Civil Engineering and nine in the Journal of the Faculty of Civil Engineering and Architecture. The conference proceedings consist of 114 papers divided into two volumes.

The total number of authors and co-authors accepted for publishing at SINARG 2023 exceeds 320. Out of this number, more than 80 authors come from abroad, representing 19 countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Germany, Greece, Hungary, India, Indonesia, Netherlands, North Macedonia, Montenegro, Oman, Poland, Romania, Serbia, Slovakia, Turkey, United Kingdom).

The editors express their gratitude to all the authors for their participation and to the reviewers for their valuable comments, which have contributed to the improvement of the original manuscripts and have enhanced the overall quality of the conference..

Niš, September 2023 *Editors*

CONTENTS

CLASSIFICATION OF RAILWAY SUPERSTRUCTURE RECONSTRUCTION METHODS

Jelena Dimitrijević[1], Zlatko Zafirovski[2]

Abstract

The concept of railway reconstruction represents a form of corrective maintenance when regular continuous maintenance cannot restore the railway to a functional condition. Renovation is most often focused on the elements of superstructure such as ballast, sleepers, fastening system and rails. In the circumstance that the substructure additionally has to be repaired, all related operations are transformed into preparatory operations and take precedence over all procedures involving the restoration of the superstructure. The chosen method of construction has a direct impact on the quality of construction and the efficiency of operations. The required quality is directly related to the category of railway being built, with higher requirements as the railway ranks higher and has higher projected speed. Aside from the required quality and efficiency of construction, the chosen method is also influenced by the available space for maneuvering the machinery. The paper provides a basic classification of methods for restoring railway superstructures, with specific references to the positive and negative aspects of each method.

Key words: *railway superstructure, railway reconstruction, railway's superstructure mechanized renewal*

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1. INTRODUCTION

Railway superstructures form the vital infrastructure that enables safe and efficient rail operations. The elements of superstructure, including ballast, sleepers, fastening systems and rails, are subjected to constant stresses and strains due to heavy traffic loads, adverse weather conditions and the natural wear and tear of daily operations. Over time, these factors can lead to the deterioration of railway superstructure, compromising their integrity and functionality. To ensure the continuous and reliable operation of railways, regular maintenance and repair efforts are undertaken. However, in some cases, the extent of damage or deterioration may exceed the capabilities of regular maintenance procedures. Railway reconstruction represents a form of corrective maintenance employed when regular continuous maintenance fails to restore the railway to a functional condition.

In this paper, a comprehensive analysis and classification of methods employed for maintaining and restoring railway superstructures is provided, considering the positive and negative aspects associated with each method. Certain methods are equally used for regular and corrective maintenance. Therefore, this classification will include all measures, both for maintenance and track correction, which return the track to a usable state in accordance with the relevant regulations [1].

Traditional manual methods, mechanized renewal techniques and advanced technologies such as automated track construction systems are analyzed based on their positive aspects, including improved construction speed, enhanced quality control and reduced labor intensity. The negative aspects, such as high capital investment, particular workforce requirements and potential limitations in certain terrains or constrained work areas, are also discussed [2].

The selection of an appropriate construction method directly influences the construction quality and operational efficiency. It is influenced by various factors. The category of railway being built plays a crucial role in determining the required quality standards. Higher-ranking railways and those designed for higher speeds demand more stringent quality requirements to ensure safe and efficient operations [3]. Furthermore, the method selection is influenced by the available space for maneuvering construction machinery. Factors such as track geometry, alignment, track stiffness and ride comfort are considered during the decision-making process.

Improving an existing track requires predicting the likely rate of track deterioration as a function of variables related to the train and its periodicity. So far, there are currently no track deterioration methodologies available to examine the condition of a railway track [4].

The findings of this paper provide valuable insights for railway authorities, engineers and researchers involved in railway reconstruction projects. The classification of methods, along with the evaluation of their positive and negative aspects, will facilitate informed decision-making and contribute to the successful restoration of railway superstructures. Ultimately, this study should direct to appropriate model development for scheduling and planning maintenance work, as well as emerging research trends and potential holes in the corresponding decision-making models [5].

2. CLASSIFICATION OF METHODS

The appropriate methods for railway superstructure restoration are categorized into three main groups: traditional manual methods, mechanized renewal techniques and advanced technologies. Each method offers distinct advantages and considerations related to construction speed, quality control, labor efficiency and capital investment [2, 6].

Table 1. Method presentation according to purpose of application

<table>
<tr><th></th><th>Method</th><th>Resources</th><th>Maintenance</th><th>Renewal</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Traditional manual methods</td><td>Skilled workforce</td><td rowspan="3">x</td><td rowspan="3"></td></tr>
<tr><td>Hand tool</td></tr>
<tr><td>Easy machinery</td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">Mechanized renewal techniques</td><td>Skilled workforce</td><td rowspan="4">x</td><td rowspan="4">x</td></tr>
<tr><td>Qualified machinists</td></tr>
<tr><td>Machinery</td></tr>
<tr><td>Heavy machinery</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Automated track construction systems</td><td>Qualified machinists</td><td rowspan="3"></td><td rowspan="3">x</td></tr>
<tr><td>One machine chain (Removing old and installing new superstructure elements)</td></tr>
<tr><td>One machine chain (installing new superstructure elements)</td></tr>
</table>

2.1. Traditional Manual Method

Traditional manual methods involve manual labor and conventional construction techniques. These methods typically require a skilled workforce to carry out tasks such as track removal, ballast replenishment, sleeper replacement and rail installation. Traditional methods have been widely used in railway reconstruction projects for many years and offer several advantages. They are generally adaptable to various terrains and work areas, making them suitable for projects with limited access or complex site conditions. These methods also provide flexibility in adjusting construction processes based on on-site conditions and challenges. The tasks can be done quickly and easily, with no need for interrupting traffic. No additional preparation or procedure is required. They are appropriate for sudden and dangerous situations where immediate intervention is required. Hand tools and small machinery are typically used for this type of work.

However, traditional manual methods can be labor-intensive and time-consuming compared to mechanized or automated approaches. They may require a larger workforce and longer construction durations, which can impact project timelines and costs. Quality control may also be more challenging with manual methods, as they rely heavily on the skills and experience of the construction workers. Additionally, these methods may have limitations in terms of achieving high construction speeds and maintaining consistent quality across large-scale projects.

2.2. Mechanized Renewal Techniques

Mechanized renewal techniques utilize specialized machinery and equipment to carry out various tasks involved in railway superstructure restoration. These procedures aim to improve construction speed, quality control and labor efficiency [7]. Mechanized techniques can include the use of track-laying machines (cranes), ballast cleaner, rail grinder, mechanized ballast tampers, wagon plateaus, rail threader, track stabilization machine, bulldozers and automated rail welding systems, among others.

Although certain procedures, such as re-ballasting and rail re-profiling, are classified as maintenance operations, they improve track performance and lead to improved quality of ride, fewer track defects and greater train stability. These methods also contribute to enhanced safety by minimizing the risk of derailments and track failures. Despite just being partially completed, this renovation is very significant overall. Superstructure assistances, such as re-ballasting, sleeper replacement, rail re-profiling and fastening system upgrades, both maintenance and renovation methods are discussed, highlighting their contributions to improved track stability, load-bearing capacity and ride quality.

Re-ballasting is a common and often used procedure in superstructure renovation. The very brief lifecycle of the ballast layer is a contributing factor in the ballast track's comparatively high maintenance expenses. It has been demonstrated that the technology of the machinery used to carry out the procedure has a significant impact on the efficiency and durability of ballasting (vertical and side tamping method) [8]. Re-ballasting involves the removal of old and worn-out ballast and the replacement with fresh ballast material. This process helps to restore the track's stability by providing a solid foundation for the sleepers and rails. It also assists in maintaining proper drainage and reducing track settlement issues [9]. Re-ballasting enhances the load-bearing capacity of the track, allowing it to support heavy train traffic and reduce the risk of track failures. This procedure is more appropriate for routine maintenance, but considering how much it improves the condition of the superstructure, it is comparable to the quality reached when installing new track.

Rail re-profiling is another represented technique employed in superstructure correction. It is simultaneous maintenance and renovation process. Continuous train traffic can cause wear and deformation on the rail profiles, leading to irregularities and an uneven track surface. Rail re-profiling involves the removal of excessive metal from the rail's running surface, restoring the desired profile. This procedure improves ride quality, reduce track noise and maintain proper wheel-rail contact, thereby enhancing safety and comfort for train operations. The technology of re-profiling is the focus of current research in this maintenance measure [10]. Rail re-profiling machines are utilized for such purposes. The benefit of preventive against remedial re-profiling is really significant [11].

One of the most important repairing activities of superstructure is the replacement of sleepers when fields or sections are replaced. Such procedures require appropriate substrate preparation and nearly every rail replacement. Sleepers, provide support and stability to the rails. Over time, sleepers may deteriorate due to decay, insect infestation or mechanical damage. In the renovation process, damaged sleepers are replaced with new ones to ensure a reliable and sturdy track structure. Mechanized sleepers replacement includes replacing smaller fields or continuously replacing on the area where the reconstruction is planned. Cranes are used for setting sleeper fields using either the ready-made fields approach (Figures 2) or the continuous method (Figure 1) [2, 12]. In the case of a lack of space, alternate methods for laying ready-made fields, including the one shown in Figure 3, can be used.

Figure 1. Removal of new sleepers from wagon plateau to intended position, using gantry crane (continuous method)

Figure 2. An example of ready-made field's method for sleepers setting down [13]

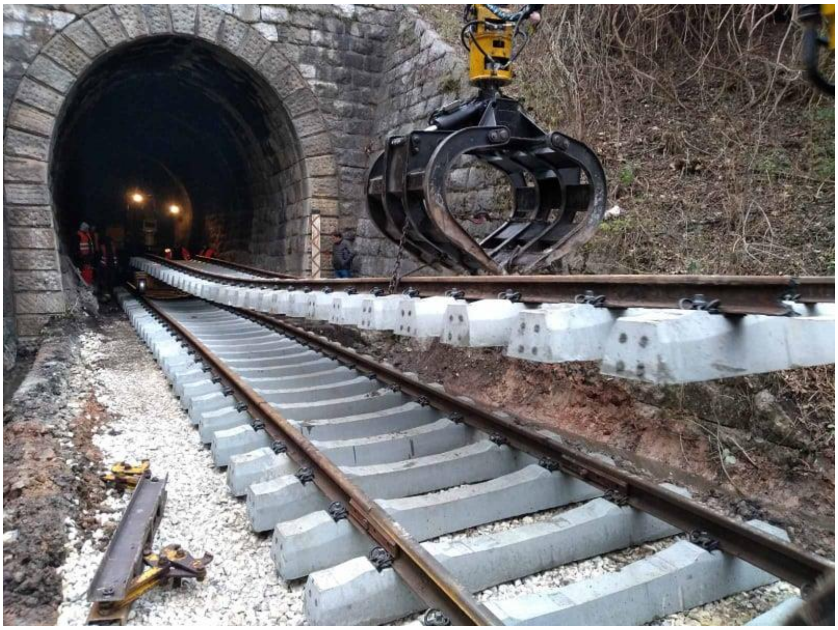

Figure 3. An example of ready-made field's method when it is impossible to utilize a crane due to a lack of space

Upgrading the fastening systems is also a critical aspect of superstructure renovation. Fastening systems, such as clips, bolts, and plates, secure the rail to the sleepers and ensure proper alignment. Over time, these components may become worn or damaged, compromising the stability of the track. Upgrading the fastening systems involves replacing worn-out components with new, more robust ones. This process helps to maintain proper rail alignment, reduce track maintenance requirements and enhance the overall track performance.

Work on the installation of new switches should be classified as a special type of work during the superstructure renovation. These operations can be done as part of routine maintenance, independently of the rest of the track, or as part of the reconstruction of a specific segment. Switches could be transported and installed in sections or as a single unit, depending on the available machinery and transportation conditions [6].

Mechanized renewal techniques offer significant advantages in terms of increased construction speed and productivity. The use of specialized machinery enables faster track laying, ballast compaction and rail installation. These methods also provide improved precision and quality control, resulting in more consistent track geometry, alignment and stability. Mechanized techniques can reduce labor intensity and minimize the reliance on manual labor, thereby optimizing workforce utilization and potentially reducing construction costs.

However, it is important to consider certain challenges associated with superstructure renovation. Specialized equipment and machinery are often required to carry out these tasks effectively. Skilled labor and expertise are necessary for the precise execution of renovation techniques. Additionally, construction activities during superstructure renovation may cause temporary disruptions to train operations, necessitating careful scheduling and coordination to minimize inconvenience to rail users.

Mechanized renewal techniques may require substantial capital investment in acquiring and maintaining specialized equipment. Skilled operators and maintenance personnel are necessary to operate and manage the machinery effectively. Additionally, certain terrains or constrained work areas may pose limitations on the use of large-scale mechanized equipment. Proper planning and evaluation of site conditions are crucial to determine the feasibility and efficiency of mechanized renewal techniques.

2.3. Advanced Technologies

Advanced technologies, such as automated track construction systems, represent the cutting-edge approaches in railway superstructure restoration. These systems incorporate advanced robotics, computer-controlled processes and artificial intelligence to automate various construction tasks. Automated track construction systems include one part construction technology [6].

This is entirely related to the reconstruction procedure. Automatic track construction systems can be used in two different ways. In the first instance, it is a composition that removes and replaces the old superstructure components in a single pass. The second scenario only involves the process of arranging new parts on a previously created substrate. The lone exception is track stabilization, which includes a time delay between installation and full track stabilization [2].

The use of advanced technologies offers significant advantages in terms of construction speed, precision and quality control. Automated systems can achieve high construction speeds while maintaining accuracy and consistency in track geometry, alignment and other critical parameters. These technologies reduce the reliance on manual labor, leading to improved workforce efficiency and reduced construction time. They also provide enhanced quality control through real-time monitoring and adjustments during the construction process.

However, advanced technologies come with higher capital investment costs and may require specialized expertise for operation and maintenance. The implementation of automated track construction systems may be more suitable for large-scale projects with well-defined track requirements and consistent work areas. Certain terrains or constrained work areas may pose challenges for the deployment and maneuverability of robotic or automated systems, necessitating careful evaluation of site conditions and project specifications.

3. METHOD SELECTION

The selection of an appropriate construction method for railway reconstruction is a critical decision that significantly influences the quality of construction and the operational efficiency of the railway. The chosen method must align with the specific requirements and considerations associated with the project, ensuring that the reconstructed railway meets the desired standards and operates safely and efficiently [7].

In Figure 4. major factors influencing method selection are presented.

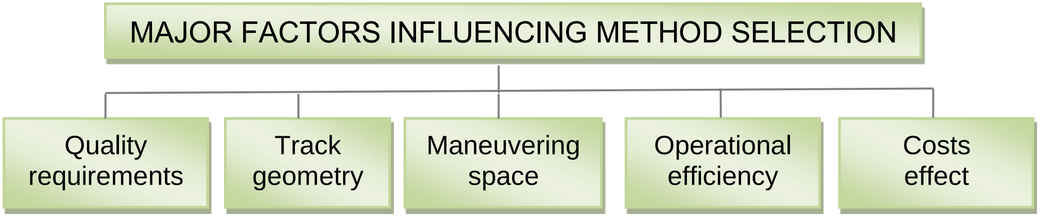

Figure 4. major factors influencing method selection

Quality considerations play a fundamental role in the method selection process. The category of railway being built is a primary factor that determines the required quality standards. Railways with higher rankings, such as high-speed or mainline railways, demand more stringent quality requirements compared to lower-ranking or branch line railways. Higher-ranking railways often have stricter tolerances for track geometry, alignment, and track stiffness to ensure safe and reliable operations at increased speeds. The selection of a method must take into account these quality standards to meet the specific needs of the railway being reconstructed.

Track geometry, which includes parameters such as gauge, alignment and curvature, has a significant impact on the method chosen for reconstruction. Different methods may be more suitable for specific track geometries, ensuring accurate alignment and geometry control during construction. Considerations for ride comfort, such as minimizing track irregularities and ensuring smooth transitions between track sections, are also important factors that influence the method selection process.

The availability of space for maneuvering construction machinery is another crucial consideration in method selection. The chosen method must be feasible and efficient within the given work area. Space constraints can limit the use of certain construction techniques, such as large-scale mechanized or automated methods. In such cases, alternative methods that can accommodate the available space while maintaining construction quality and efficiency need to be considered.

The efficiency of the selected construction method is crucial for timely completion and cost-effectiveness of the reconstruction project. Methods that offer faster construction speeds, enhanced quality control and reduced labor intensity can contribute to improved operational efficiency. Mechanized or automated methods, such as track-laying machines or automated track construction systems, can significantly accelerate construction processes and reduce reliance on manual labor.

However, it is important to note that the selection of certain advanced or mechanized methods may require specialized equipment, skilled workforce, and higher capital investment. These factors need to be considered during the decision-making process, weighing the potential benefits against the associated costs and resource requirements [14].

4. CONCLUSION

By examining traditional manual methods, mechanized renewal techniques, and automated track construction systems, this paper has provided valuable insights into the advantages and considerations associated with each method.

The comprehensive analysis and classification of methods for restoring railway superstructures presented in this paper serve as a valuable resource for practitioners and researchers involved in railway reconstruction projects. By leveraging this knowledge, stakeholders can make informed decisions, enhance the quality and efficiency of railway reconstruction, and contribute to the safe and reliable operation of railway systems.

In summary, the selection of an appropriate construction method for railway reconstruction involves, among others, careful consideration of quality requirements, track geometry, efficiency, cost-effectiveness and the availability of space for maneuvering machinery. By aligning the chosen method with these considerations, railway authorities and engineers can ensure that the reconstructed railway meets the desired quality standards while maximizing operational efficiency.

Due to the complexity of decision-making when determining a technique and taking into consideration relevant factors in decision-making, it would be beneficial in the future to focus on the development of decision-making models. The process of degradation of the superstructure might be predicted by continually monitoring the track condition parameters. As a result, the on-going interventions on the track mandated by the regulations, would be replaced with meaningful regular and corrective maintenance specific to the railway in question and its superstructure elements.

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