IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 6 Ser. II (Nov. – Dec. 2021), PP 41-51
www.iosrjournals.org

A Study on settlement and deformation characteristics of high speed railway with ballasted track and ballast less turnout Area

Minhaz Ahmed[1], Wang Xu[*1]
[1]School of Civil Engineering, Lanzhou Jiaotong University, China
Corresponding Author: Wang Xu

Abstract
These days, trains may be able to compete on an equal footing with aero planes on a serious basis. When properly constructed and maintained, the railway may serve as a mode of transportation, reaching speeds of up to 300 kilometers per hour or more.
The development, material quality and manual manufacturing of pre-stressed concrete made concrete railroad ties popular in Europe after World War II. As ever, concrete ballast sleepers are the fundamental foundation of road building throughout the globe, but equally popular and extensively utilized are twin-block concrete sleepers. With operating loads and speeds constantly rising, railway firms have been compelled to upgrade their technological and economical systems to maintain their essential position in the movement of people and goods. The superstructure of the rail system in china had a very significant part in this evolution and this process of modernization led to the ballastless track system being established about 60 years ago. In this article, two major kinds of track systems are compared, including all other important factors, as material and track requirements, manufacture, lifespan, economics, and environmental problems, must be investigated and compared.
China has the longest high-speed rail network in the world with over 35 000 kilometers of expressway lines in operation. Chinese high-speed railroads are three times the distance from the European Union to this end. China's express network is not only the world's largest, but also China's fastest running trains. Today, the country is recognized as a global rolling stock powerhouse. High-speed train is a low-emission technology that reduces passenger/km power consumption on roads and passengers. Infrastructure construction may, however, involve significant consequences for existing ecosystems and cost money if tunnels are required. High-speed rail investment is expected to return with huge economic and social consequences by significantly enhancing the flow of resources and commodities in China as part of the central government. The business is also a symbol of Chinese unity and innovation by connecting rural areas with China's major economic hubs.
Keyword: *Faster trains, ballasted track, ballastless track, deformation of high speed trains etc.*

Date of Submission: 01-12-2021 Date of Acceptance: 15-12-2021

I. Introduction

1.1. Background

Development of the railway track's construction may be accomplished via a variety of ways. Ballasted rails are the most often used kind of railing. In addition to ballast tracks, there are also ballastless tracks, which were developed in the 1970s and are still in use (Dahlberg, T., 2004). There were many major motivations for the development of ballastless tracks, including the need for a track that required less maintenance and had lower maintenance costs.

The transition zone is an area where there is a greater need for maintenance, particularly in the case of rail line maintenance. Studies have shown that the transition zone between ballast and ballastless railways is the weakest link in the route (Sysyn, M.P., 2019).

1.2. Aim of the research paper

The purpose of this paper is to examine and compare the ideas of ballasted and ballasted paths with technical and economic factors. This comparison is essential to understand the settlement and deformation characteristics of high speed railway within these tracks. In order to better know the economic benefit of a ballastless track in the long run, a simpler life cycle cost analysis is developed. The research findings should not be concluded that under all circumstances one system is superior to the other. However, it may be utilized as a foundation for a broader study.

II. Research Methodology

In this study, the qualitative technique will be used. Aside from that, the author gives a comparison between ballast and ballastless rail tracks. The data for this study was gathered using secondary and qualitative methods. To come up with the conclusions, the researchers used a variety of strategies, including reading several articles and evaluating case studies from throughout the world.

III. Ballasted and Ballast less tracks

There are a large number of distinct track systems worldwide. The most popular track types are divided into 4 groups in this section. For each kind, short information is provided. More detailed information regarding ballast tracks is subsequently provided so the features of high-speed trains on these tracks can be understood.

3.1 Ballasted track

Today, nearly all extant railway lines are mostly ballasted. Sleepers and rails in a layer of granular material called as ballast comprises of this type of track system. The building concept of the standard track structure is shown in Figure 1.

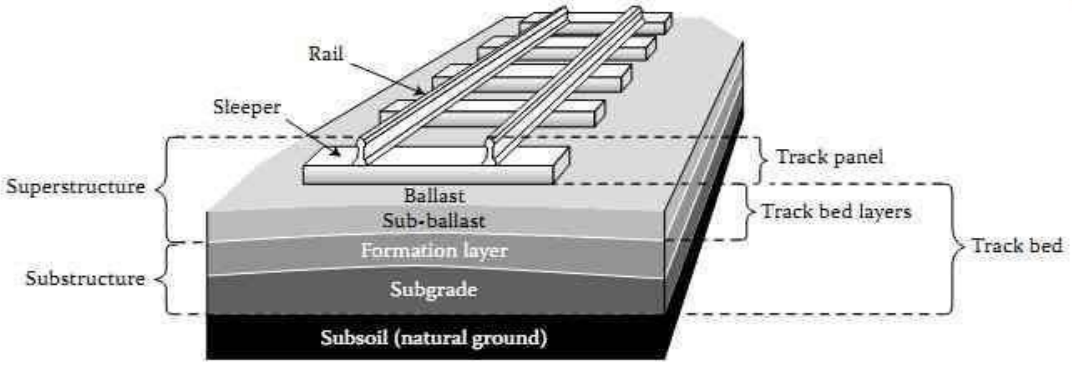

Figure 1 Cross-section of ballasted track 1

The concept of the ballasted track construction hasn't altered much since the inception of the railroads, the experts say. Important post World War II innovations include the introduction, maintenance mechanization and the introduction of sophisticated measurement systems, heavy rail profile systems, and the creation of continuous weldened railways (Wang, P., Wang, 2016). This allows for significant demands to be met in the conventional ballasted superstructure.

At one point in the early stages of railway engineering, the importance of ballast in terms of capacity was not fully appreciated. Horses were used as mode of transportation in the beginning. When big locomotives are discovered, the layer under the sleepers must be sufficiently deep to transmit the weight to the ground, thus guaranteeing that the track will remain stable. Nowadays, the required ballast depth varies depending on the vehicle's speed, axle weight, and annual total tonnage.

The rails are supported by sleepers in the ballasted track. According to their convenience, availability, cost-effectiveness, and aesthetics, there are many different kinds of sleepers that are utilized in railroads. Timber and concrete sleepers, as well as steel sleepers - to a lesser degree - are now in use.

The sleepers are responsible for performing the following fundamental functions. Wheel loads

- Disseminating ballast wheel loads.
- Hold the rails to the gauge and inclination that you want.
- Send lateral and longitudinal forces to the recipient.
- Electrically insulating the rails.
- Provide the rail seat and fixing foundation.

Figure 2 Overview of different tracks

Using fastening systems sleepers and rails are linked. The technology provides a durable rail-sleeper link to withstand all stresses resulting from traffic and temperature changes.

The general roles and needs of the attachment systems are.

- To absorb and transmit the rail stresses into the sleeper elastically;
- To minimize vibration and the effects of traffic;
- To maintain a particular tolerance of the gauge and slope of the rail;
- Electrical isolation between the rails and sleepers, in particular for sleeping concrete and steel.

The attachments may be separated into two different kinds, stiff and elastic. The installation of a continuous welded railway line led to the requirement for more elastic fastenings. The elastic systems in today's applications are thus more extensively utilized. Depending on the characters and the sleepers' construction there are many alternative kinds of attaching methods, but one set consists usually of 4 screw pins, 4 screw dowels, 4 voltage clamps, 4 plates and 2 track pads.

Figure 3 Vossloh W14 Rail Fastening System

3.2 Ballast less track

The bulk of today's railroads are still ballasted in the conventional sense, although emerging uses are becoming more unballasted. Ballast material is used in place of ballast in ballastless track applications. A concrete ballastless ballast material is used to provide track support in ballastless applications. In most cases, the sleepers are also included into the ballastless concrete mix (Matias, S.R. 2020). The rails are equipped with a kind of attachment that is comparable to that used on ballasted railway systems.

Figure 1 Ballast less track

The main driving force for the creation of ballast less tracks was the increase in speed. When the train's speed reaches a particular level, the track structure and the supporting ground become very dynamic as a result. With these motions, the track, ballast, and sub ballast degrade rapidly, increasing the likelihood of derailment and soil collapse. Ballastless trains, which are already in use in many nations for high-speed trains and are regarded as safer and more convenient rail systems, are becoming more popular. However, it is not just the speed that makes the ballastless route more appealing; it is also the fact that it is shorter. Investment costs have been assessed in recent projects, and the results of these studies show that, when compared to ballasted tracks, ballastless lines are much more expensive. When life cycle costs are taken into consideration, ballastless track systems may in fact provide more competitive pricing even at modest speeds (Avramovic, N., 2010).

3.3 Deformation of Ballasted track

There are lots of one-of-a-kind things in the ballast. It is low in cost, easy to manufacture, and, in addition to its mechanical properties, it allows for alignment adjustments to be made. When exposed to dynamic loads over an extended period of time, ballast begins to degrade and progressively degrades a condition that seems to be undesirable when track geometry varies. Because of the weak sub grades and inadequate drying, it gets contaminated with clay pump, causing rails to buckle and, as a result of a lack of confining pressure, the sleeper snaps in half. It has been decided in a different way. These difficulties connected with road foundations result in expensive railway maintenance, which includes the cleaning and replacement of ballast, as a result of the problems.

Figure 2 Track fouls due to mud pumping

Figure 6 Track settles differentially

Figure 3 Track buckles due to lack confining pressures

The main reasons which cause track performance deterioration are mentioned below.

- o Material standards mismatch.
- o High dynamic and static soil pressure.
- o Load repeated.
- o Inadequate soil compaction or volume loss.
- o Inadequate, easily broken use of material.
- o Ballast density is missing.

- Lack of ballast and ballast cleaning frequency.
- Low drainage characteristic.
- High soil waters.
- Sleeping too small with too little space.
- Effects on the environment such rain, wind, vegetation and erosion.

Different mitigation methods may be used to overcome or decrease the degree of track degradation.

- Improved ground stability.
- Geosynthetics track reinforcement.
- Training stabilization to improve chemical and physical capability.
- Use of precast vertical drains.
- Choice of high-quality ballast with suitable ballast-reducing characteristics.
- Sufficient pressure container and ballast on the shoulder

As a result of the degradation of track; wear on rails more quickly, sleepers are overloaded and break down. The deterioration to the track causes low-speed areas and therefore reduces service levels. Track calls for greater maintenance and renewal of the component. The railway lifespan is reduced (Avramovic, N., 2010).

3.3.1 Ballast taint

In many nations across the globe, ballast pollution is an important element in the deteriorating track. Contaminated ballast fills the valve and impacts the drainage capacity. Lubricant leaking over time leads in a lower ballast layer load-bearing capability. The ballast layer is wasted and may be transported by rain water from lubricants into soil and ground water, from dangerous chemicals (notable NI, Zn, Fe, Cd, V, Cr, Mn, Cu, etc.) (Gallou, M., 2018).

Below are the main causes of ballast pollution.

- Fines after placement of ballast.
- Aerial sediments.
- Mines from overloaded cars like coat fall.
- Fine particles from the subsoil ascending.
- Remaining vegetation.
- Railway and wheel fines wear.
- During tamping, particles brushed off.

It has also been shown that the stability track of the sealing void has a substantial effect on the biodegradation products generated by organic plants. Short-root plants give water and minerals to moist gravel while also covering the surface of the ballast. As a result, the particles decrease the strength of the ballast to a level that is nearly equal to the shaving strength of the gravel, practically.

3.3.2 Duration of life

The service life of the railway is extended when its components are replaced. The anticipated lifetime of the track is almost equal to the ballast. The track consists of four major components.(Giunta, M. and Praticò, 2017). Table 1 below shows the common components and their life expectancies.

Table 1 Track components and expected service life

Component	Characteristic	Service life [Years]
Rail	UIC 60	28
Sleeper	Pre-stressed mono-block	40
Fastenings	ElasticTypeVoslohW14	40
Ballast	Crushed stones	40

The longevity of the ballast material cannot, however, be precisely determined. It relies on a number of variables like material quality, maintenance, axle load, weather, etc.

Most railroads in the world today are ballasted. The existing asset volume is such that the supremacy of the ballasted railway will unlikely alters in the very near future, even when new railroads are constructed on ball stop roads. During its lifespan, the ballast track may be subjected to 10 maintenance tamps until ultimately renovation is necessary. Maintenance work is expensive activities which take on the operating budget lion's share. In addition, while this operation services are interrupted and extra non-monetary expenses such as user delay, substitute bus service traffic, etc. are generated (Avramovic, N., 2010).

3.3.3 Repairing

Track maintenance involves providing maintenance and repair to guarantee that the track complies with safety and quality requirements in the most affordable manner necessary for both the railway and its vehicles. If the reduction in the depreciation is dominated by the rise in maintenance costs, its service life is considered to have finished. The major maintenance procedures are summarized in the table 2 below and approximate repeater times.

Table 2 Cyclic maintenance operations

Repairing operations	Cycle [Years]
Tamping	4-5
Grinding	1-3
Cleaning	12-15
Rail replacement	10-15
Sleeper replacement	30-40
Rail fastenings	10-30
Replacement of ballast	20-40
Soil rehabilitation	>40

The different rail components, as well as their linkages, may have an impact on the amount of maintenance required. Maintenance operations should be carried out in accordance with observations and measurement equipment, which is especially important owing to the unpredictable behavior of soil (Avramovic, N., 2010). The degradation trends of a specific segment, as well as the deterioration patterns of a single component, may be monitored in order to predict the maintenance cycle of the whole route.

3.4 Deformation of Ballastless track

The ballastless track is intended to be maintenance free or low throughout its life cycle (50- 60 years). As with the ballast track, however, throughout the service life of the ballastless track, no significant interventions are anticipated (Orel, E.G.,). The geometry of the route may only be deteriorated when abrupt and unpredictable events like derailments occur. At that time, the damage caused by derailing or environmental impacts, such massive waste settlements can only be remediated by extremely costly methods. It takes a considerable time to remove and construct a new broken concrete track. This implies complete termination of the connection and interruption to the service. However, substitution bus services entail extra costs. The quality of the ballastless track should be ensured via appropriate high levels of quality assurance procedures. This means that construction activity is subject to extra costs and time and oversight. Any quality defect would persist throughout service and can only be remedied via costly solutions. For example, the onsite repair of Rheda System may result in lengthy closure owing to the completion of the manufacturing process. The prefabricated buildings, such as ÖBB-PORR, may solve this issue. According to ÖBB, track stoppages are maintained to a minimum, and the repair or replacement takes relatively little space to continue to run the parallel track (except in tunnels). Within three to four hours the plates may be simply removed and changed (Lu, C. and Cai. 2020).

Figure 8 Application of ÖBB-PORR System

3.4.1 Duration of life

Theoretically, with at least 60 years of design life, a concrete ballastless path is constructed. The track components (rail, fasteners, plates, etc.) have a greater life span than conventional tracks thanks to their superior track alignment; it would be very acceptable to take 60 years to live the ballastless track system (Giunta, M. and Praticò, 2017).

3.4.2 Repairing

Except in the case of non-track systems like as rail grinding, maintenance is seldom necessary. The oldest stretch in Austria has remained in operation without maintenance and service charges since 1989, according to the Austrian Railway Corporation (ÖBB).

Different kinds of ballastless railway need a variety of upkeep. These kinds are classified in the next area and the most widely used systems are discussed in more depth.

IV. Discussions and Results

4.1 Ballasted Track for High Speed Trains

Conventional railway lines are equipped with many benefits such as cheap cost construction, excellent drainage, minimal noise emission, geometry changes and simple maintenance. Displacement behavior between sections and degradation is believed to be related to the inherent characteristics of the ballast material. Research has revealed that dynamic forces are quickly increasing as train's axle weight and speed rise, reaching critical vibrational levels. High vibration values accelerate track degradation and deformation and provide serious safety challenges. The ballast vibration rate of 20 – 26 mm/s was observed on the new high speed ballast rails. Standard values between 10 and 15 mm/s are taken into account (Cai, X., Zhao, 2015).

Sunburn is a basalt-related phenomena or substance linked to basalt. These materials tend, when they suffer air impacts, to create gray-white colors, to develop fractures which damage the material's structure and ultimately weaken the whole substance. Depending on the rock's origin, this may happen within many months.

A significant issue at high speeds of over 300 km/h is ballasting as well as early deterioration of rolling equipment and rail. The problem with ballast flying is very severe. The speed of operation of high-speed trains over ballast tracks is thus constrained (Björkquist, W. and Janjua, 2020).

A large amount of turbulent airflow occurs on a ballast bed as a result of the train's underlying boundary layer and disturbances to irregular components of the train, such as proud bogies, creating a heavy amount of turbulent airflow. The wind velocity may reach up to 50 m/s and is responsible for pulling the ballast into the route. Dragged ballast not only causes damage to the train, but it also accelerates the deterioration of the track. Damaged wheels and glass broken at the station have all been reported as a result of ballast flight injuries on many occasions (Kedia, N.K., Kumar, 2021).

According to researchers, after a large number of high-speed train operations over ballasted track, the following conclusions have been drawn:

- The use of ballasted rails for this purpose is highly demanded due to the need for uniformity in all aspects.
- The thickness of the ballast layer and, therefore, the accuracy of the top of sub grade geometry are very important considerations.
- Regarding long-term track stability, it is necessary to have a ballast bed that is the proper and consistent width.
- The rigidity of the sub grade should be as uniform as is reasonably practicable.
- Turnouts must be matched onto the track in the smoothest possible way to function properly.
- Integration of ballasted track with ballastless portions (at bridges, for example) must be handled with care throughout the engineering phase.
- In order to prevent any damage caused by the action of water, the subgrade must be properly drained.
- The track gauge must be selected in order to ensure that the vehicles have good running characteristics. Practical experience has shown that gauges less than 1435 mm (when using standard gauge) may create wheel set instability at high speeds when using a standard gauge.

The following are the characteristics of traditional ballasted track for high-speed lines:

- UIC60 is a class of train.
- Sleeper of type B70W with 60-centimeter spacing.
- In the event of poor settlement behavior, use a stiff rail pad of type Zw687a with an elastic coefficient of 500 kN/mm or a highly elastic rail pad of type Zw900 with an elastic coefficient of 60-70 kN/mm.
- 30 cm is the depth of the ballast bed.
- Formation protection layer and frost protective layer that have been highly compacted.

Figure 4 High speed train on ballasted track

4.2 Ballast less track for high speed trains

A ballastless track structure is used to pave the majority of high-speed railway lines across the globe in order to enhance the dynamic performance and stability of the track and its substructure. Because ballastless track constructions offer greater longitudinal and lateral permanent stability, as well as improved smoothness, they provide structural and operational benefits over ballast-filled track structures (Jadidi, K., Esmaeili, 2021). High-speed and traditional main line rail infrastructure design, ballastless track system design, specific features of the Metro and light-rail systems, interactions between trains, and the layout and alignment of the urban rail system are all topics covered in this course (Gautier, P.E., 2015).

In the mid-1960s countries began developing ballastless tracks for fully operated railroads with the design of lengthy tunnels where the rails had to be placed on a solid rock or concrete foundation directly (Kedia, N.K., Kumar, 2021).

The Fast Track section components are:

- Both SMA 11 and AC 22 S bituminous agglomerates are used in the construction of this structure. SMA 11 is a sustainable bituminous agglomeration that is used mostly on high-capacity roads, whereas AC 22 S is a hot bituminous agglomerate that is utilized on all roads.
- A concrete slab constructed using HA-25 and BS-400.
- In order to prevent horizontal or vertical deformations, concrete retainers are required.
- Two layers of attenuation pads are used to dampen the sound.

Figure 5 High speed train on ballast less track

4.3 Analysis of Ballasted track

Ballasted track technology has evolved over the course of more than two hundred years. The vast amount of knowledge gained through years of experience in ballast track construction has resulted in a wealth of information that may be used by engineers to solve ballast-free track problems (Avramovic, N., 2010). Recent improvements have improved the competitiveness of the ballast-free circuit.

When comparing ballasted track versus ballastless track, the following are the most significant advantages:

- Technology that has been proven.
- Construction costs are kept to a minimum.
- Track components are simple to replace.
- High levels of maintainability.
- Noise output is kept to a bare minimum.
- It allows for effective drainage.
- High degree of flexibility.
- It is possible to make minor adjustments to the track layout.

Building a path is quicker than ballastless, but a lot of rock is necessary. When the quarries are far off from the building site, ballast transport will increase expense and CO2 emissions. But it may still be ecologically beneficial, because a significant quantity of concrete is required during ballastless track construction and cement manufacture is one of the main emission sources (Orel, E.G.,). Moreover, ballastless cannot be carried in large quantities owing to axle load constraints. Greater operation of transport must be implemented, which will lead to more emissions of carbon dioxide.

The primary source of emissions in track building is steel manufacturing for rail (about 50 percent of the total emission). However, it displays higher emissions than the ballastless kind because of concrete manufacturing when compared to the ballastless path. According to UIC research, ballastless tracks generate higher CO2 than ballasted tracks throughout the production, installation and maintenance period (Eller, B. and Fischer, 2019).

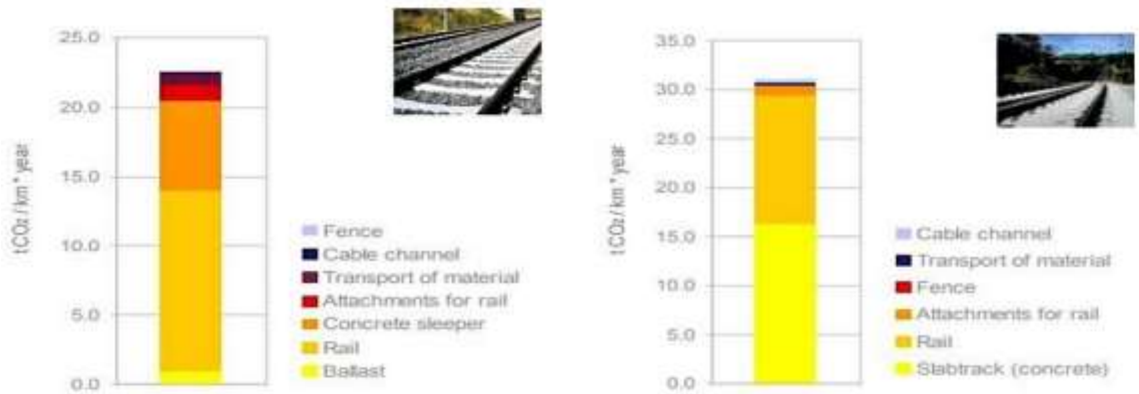

Figure 11 Carbon footprints of track ballast and ballastless tracks

Degradation in the ballast material under high traffic is the major problem of the ballasting track. A wide range of variables such as amplitude, number of load cycles, aggregate density, and confutation pressure of the track, angularity, and most important the strength of the individual grains fracture may lead to ballast deterioration (Avramovic, N., 2010).

4.4 Analysis Ballast less track

The ballast track is cost-effective in the near term but it becomes less beneficial with time. Although the primary causes for regular maintenance and speed restrictions are ballastless track. Despite the uniform design of the ballast track, however, the designs of the ballasting track vary because of the existence of several companies. Each design has many benefits but may be summarized primarily as follows.

- More stability lateral and longitudinal.
- Geometry of the rigid track.
- Longer life span (50-60 years).
- Requirement for maintenance free or less.
- Removal of churning of higher speed ballast particles.
- Enhanced operating capacity (no interruption due to maintenance work).
- Sharper curves with progressively higher values.
- Height and weight reduced structure.

- Control of vegetation is more pleasant and inexpensive.
- Without difficulty, Eddy's current brake may be used.
- The ballastless track allows emergency cars to travel.
- Allows higher slopes on the road.
- Better distribution of load.
- Excellent high-speed riding comfort.

In their research, Researchers discovered that around year 20, ballasted track surpasses the ballastless Figure 12 Development of ballasted and ballastless track types using discounted cash flow methodstrack's accumulative expenses as a result of increased maintenance expenditures (Orel, E.G.,).

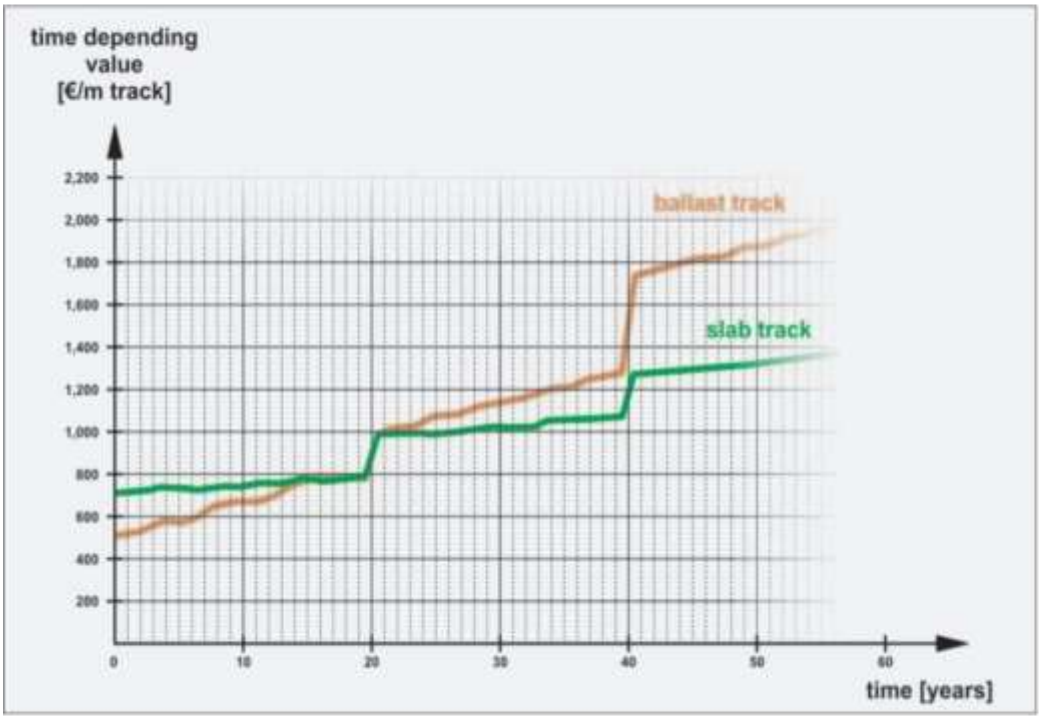

Figure 12 Development of ballasted and ballastless track types using discounted cash flow methods

The following literature lists further system disadvantages:

- Greater radiation emissions (5dB), more treatment, resulting in higher building costs, are required.
- The track may abruptly deteriorate and when the system is operationally robust.
- After its life cycle is over, the costs of rebuilding the ballastless path are not considered.
- Special care must be paid to transitions between ballast and ballastless track.
- It needs a frost protection layer of at least 70 cm thick.
- Costly maintenance and long-term closures because of the concrete's cure and hardening methods.
- Not many opportunities to apply innovation or future building upgrades.
- A building fault would persist for the whole life cycle or expensive steps need be made to remove it.

V. Conclusion

This research paper introduces several ballastless tracks and ballast systems. Detailed details are provided for each system of structures, dimensions, service life and maintenance. In addition, short mention is made of the environmental effects of railroads. In the context of these information sets, both systems debate their benefits and drawbacks.

The ballasted path is a well-established technique developed over the ages. At high speeds, the ballast track's performance limitations become apparent. The speed increase causes a quicker degradation of the track, which requires more regular repair. Moreover, the ballast material levitates and hurts at a particular speed, under the influence of aerodynamic forces. This effect restricts the pace at which high-speed trains operate over ballasted routes.

For the above stated issues, the ballastless track is a costly option. The research and analysis conducted in this study nevertheless indicate that ballastless tracks pay for the lifespan of their investment costs and become even cheaper over a longer duration. However, service is not stopped in the ballastless track systems as is the case in the case of ballasted track owing to maintenance and renovation. The system thus generates greater income.

The reparability of this ballastless path is one of the major issues. So yet, no significant ballastless track accident has occurred in a system. However, scholars say that restoration procedures may be lengthy and expensive in the event of a catastrophic catastrophe. High noise emissions are another major drawback of ballastless tracks. The use of noise barriers may avoid this issue. While these measures raise investment costs, they do not surpass 3% of the overall cost of the project.

Before implementation, their environmental consequences should be examined as well as the economic aspects of the systems. The environmental effects of this research are assessed on the basis of eCO2 emissions. Ballastless tracks significantly increase eCO2 generation than ballast. However, analyses indicate that eCO2 is more in total over extended periods owing to the use of fossil-fuelled cars during maintenance and renewal operations on the ballasted track.

Finally, it is not necessary to consider ballastless track just if it has high speed. It is cheaper, safer and more environmentally friendly in the long run.

References

[1]. Gautier, P.E., 2015. Slab track: Review of existing systems and optimization potentials including very high speed. Construction and Building Materials, 92, pp.9-15.

[2]. Cai, X., Zhao, L., Lau, A.L.L., Tan, S. and Cui, R., 2015. Analysis of vehicle dynamic behavior under ballasted track irregularities in high-speed railway. Noise & Vibration Worldwide, 46(10), pp.10-17.

[3]. Xiao, J.L., Jing, P., Yu, S.X. and Wang, P., 2020. Analysis on the track quality evolution law of polyurethane-reinforced ballasted track in high-speed railway. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, p.0954409720975572.

[4]. Lu, C. and Cai, C., 2020. Overview on safety management and maintenance of high-speed railway in China. Transportation Geotechnics Guo, Y. and Zhai, W., 2018. Long-term prediction of track geometry degradation in high-speed vehicle–ballastless track system due to differential subgrade settlement. Soil Dynamics and Earthquake Engineering, 113, pp.1-11., 25, p.100397.

[5]. Jadidi, K., Esmaeili, M., Kalantari, M., Khalili, M. and Karakouzian, M., 2021. A review of different aspects of applying asphalt and Bituminous mixes under a railway track. *Materials*, *14*(1), p.169.

[6]. Wang, P., Wang, L., Chen, R., Xu, J., Xu, J. and Gao, M., 2016. Overview and outlook on railway track stiffness measurement. *Journal of Modern Transportation*, *24*(2), pp.89-102.

[7]. Matias, S.R. and Ferreira, P.A., 2020. Railway slab track systems: review and research potentials. *Structure and Infrastructure Engineering*, *16*(12), pp.1635-1653.

[8]. Mundrey, J.S., 2010. Tracking for high-speed trains in india. *RITES Journal*, *7*, pp.1-16.

[9]. Dahlberg, T., 2004. Railway track settlements-a literature review. Report for the EU project SUPERTRACK, 463.

[10]. Sysyn, M.P., Gerbera, U., Grue, D., Nabochenko, O.S. and Kovalchuk, V.V., 2019. Modelling and vehicle based measurements of ballast settlements under the common crossing.

[11]. Orel, E.G., COMPARISON OF` BALLASTED AND SLAB TRACK BASED ON LCC ANALYSIS.

[12]. Eller, B. and Fischer, s,. 2019. REVIEW OF THE MODERN BALLASTED RAILWAY TRACKS'SSUBSTURCTURE AND FURTHER INVESTIGATION. Science and transport progress. Bulletin of Dnipropetrovsk National University of Railway Transport, (6(84)),pp.72-85.

[13]. Gallou, M., 2018. *The assessment of track deflection and rail joint performance* (Doctoral dissertation, Loughborough University).

[14]. Björkquist, W. and Janjua, I., 2020. Evaluation and comparison of ballastless tracksystems with regards to system andperformance characteristics.

[15]. Freudenstein, S., Geisler, K., Molter, T., Missler, M. and Stolz, C., 2018. *Ballastless Tracks*. John Wiley & Sons.

[16]. Avramovic, N., 2010. Comparison of ballast and ballastless tracks. na.

[17]. Pons, J.J., Sanchis, I.V., Franco, R.I. and Yepes, V., 2020. Life cycle assessment of a railway tracks substructures: Comparison of ballast and ballastless rail tracks. *Environmental Impact Assessment Review*, *85*, p.106444.

[18]. Köllő, S.A., Puskás, A. and Köllő, G., 2015. Ballasted track versus ballastless track. In Key Engineering Materials (Vol. 660, pp. 219-224). Trans Tech Publications Ltd.

[19]. Giunta, M. and Praticò, F.G., 2017. Design and maintenance of high-speed rail tracks: A comparison between ballasted and ballast-less solutions based on life cycle cost analysis. In Transport Infrastructure and Systems (pp. 87-94). CRC Press.

[20]. Kedia, N.K., Kumar, A. and Singh, Y., 2021. Comparison of Ballastless and Ballasted Track for High-Speed Train. Seismic Hazards and Risk: Select Proceedings of 7th ICRAGEE 2020, 116, p.157.

Wang Xu. "A Study on settlement and deformation characteristics of high speed railway with ballasted track and ballast less turnout Area." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 18(6), 2021, pp. 41-51.