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CONTRIBUTION ON BALLASTLESS TRACK TECHNOLOGY

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الملخص العربي :

تتطور منظومة السكة الحديدية لتواكب متطلبات الحركة المستقبلية، ويتعرض البحث الحالي لأهم أحد هذه العناصر وهو هندسة السكة، ومن مظاهر هذا التطور تحول السكك التقليدية الزلطية إلى غير زلطية نظراً لحاجاتها للصيانة الدورية المتقاربة وزيادة الإجهادات عنها في حالة إستخدام فلنكات عرضية بدلاً من الطولية، ويمكن إستخدام وسائد مرنة مع إستخدام نظام صرف مياه بدلاً من مواد التزليط، ولذا يفضل إستخدام السكك اللازلطية كبديلاً عنها.

و تعددت عناصر وخصائص هذه السكك اللازلطية بحيث أصبح من الضروري تحديد الأنسب منها وفقاً لظروف التشغيل المختلفة.

ABSTRACT:

Railway system has been continuously developed to comply with future traffic requirements, the present thesis deals with one of the most important part of this system which is "the track". One of that development is applying the ballastless track instead of the traditional ballast track which needs periodical maintenance during short times as well as the developed stress exceeds due to use transversal discrete sleepers instead of longitudinal continuous ones. To overcome the absence of ballast, elastic elements and drainage system will be provided, in such a way one can safely change the ballast track into ballastless one.

Due to numerous parameters and characteristics of ballastless track systems, it's necessary to accurately determine the most suitable system according to the different operating conditions.

KEY WORDS:

Discrete rail support (embedded sleepers, superimposed sleepers, prefabricated support without sleepers, monolithic support), continuous rail support (embedded continuous rail support, continuously and clamped), allowable speed, track total height, hydraulically bonded layer, noise assessment, construction cost, daily performance, renewal assessment, flexural stiffness.

INTRODUCTION

Traditional ballast track has great problems to construct, maintenance, and renewal, high vibrations and noise develop due to running trains especially with high speeds, traffic, and heavy loads. And practically, ballasted track has the advantage of lower capital costs but it has higher operating costs than the ballastless one.

Most of the railway tracks are nowadays still of a conventional ballasted, despite there are modern types of ballastless track were developed [1].

In the case of a ballastless track the ballast material is replaced with a concrete ballastless that provides support for the track. The sleepers are usually integrated into the concrete ballastless as well.

The rails are fastened with a similar type of fasteners as those used in the ballasted track [2], [3].

The main objectives of the present paper are to prepare a comparative study between the different types of ballastless track, and determine the most suitable system according to the different operating conditions.

1- CLASSIFICATION OF BALLASTLESS TRACK SYSTEMS

Over the years, various types of ballastless track have been developed all over the world.

In general, they can be divided in terms of their composition into two groups:

1- Continuous rail support systems which are often used in tram.

2- Other systems as shown in Figure (1).

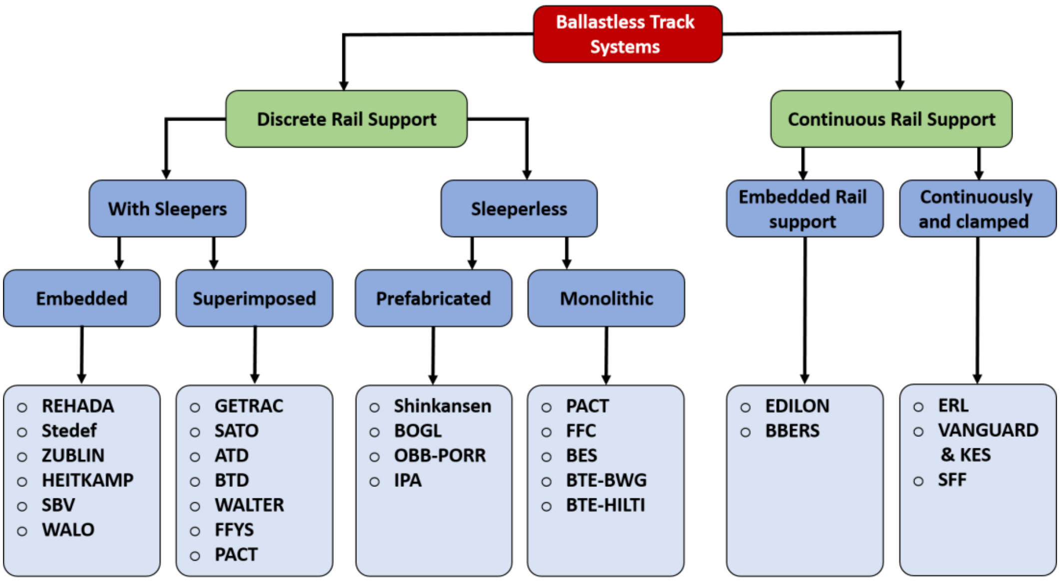

Figure (1): Classification of Ballastless Track Systems [2], [4], [5], [6], [7]

1-1- DISCRETE RAIL SUPPORT

1-1-1-EMBEDDED SLEEPERS

1-1-1-1- RHEDA SYSTEM

The basis for the Rheda is a track design that was first implemented in 1972 on the line from Bielefeld to Hamm, Germany, at a station called Rheda [8].

Rheda's design is free of any patent rights and therefore, since its birth, it has been under continuous development by many contractors and many different structural versions have been created to meet different specifications on various projects [9].

The Rheda system is highly flexible allowing for design changes and improvements in order to fit fulfill the demands of each project.

Hence, it can be found in bridges, tunnels, as well as in earth structures.

The picture (2) shows the major design versions of the Rheda system.

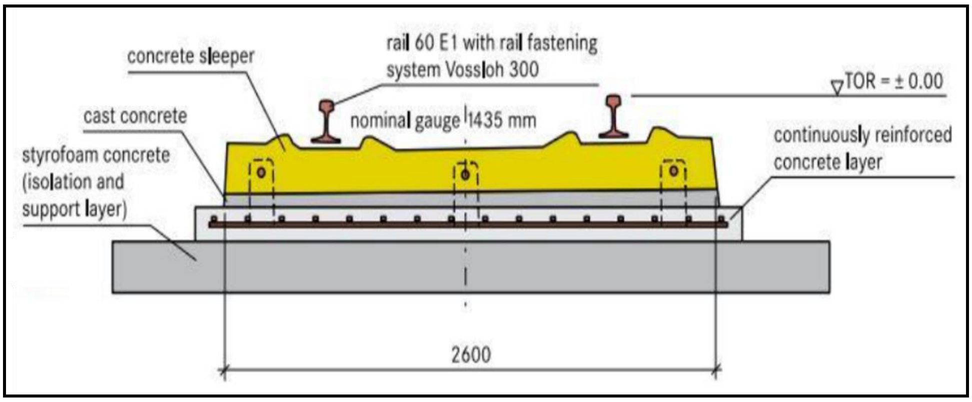

Figure (2) Rheda Classic System [10]

1-1-1-2- STEDFE SYSTEM

Underground Grater Cairo Metro in Egypt apply the Stedef track system, with a length of about 22 km for the Second Line and a length of about 18 for the First and Second Phases of the Third Line as shown in figure (3).

The Stedef system is considered a type of discrete rail support with embedded sleepers which has been built in several nations throughout the world, with at least 200 kilometers (51 km, Athens metro) having been built in Europe alone as shown in figure (4).

This method is mostly utilized in tunnels [11], this development resulted in two gains:

1. It reduces the need for complete sleeper replacement and enables damage caused by a derailment or material collapse to be repaired without the need to repair the wedging concrete.

2. It has a polyurethane waterproof seal that stops water from seeping in around the rubber boot's edges.

Figure (3) Ballastless track of third line of third ground Cairo metro

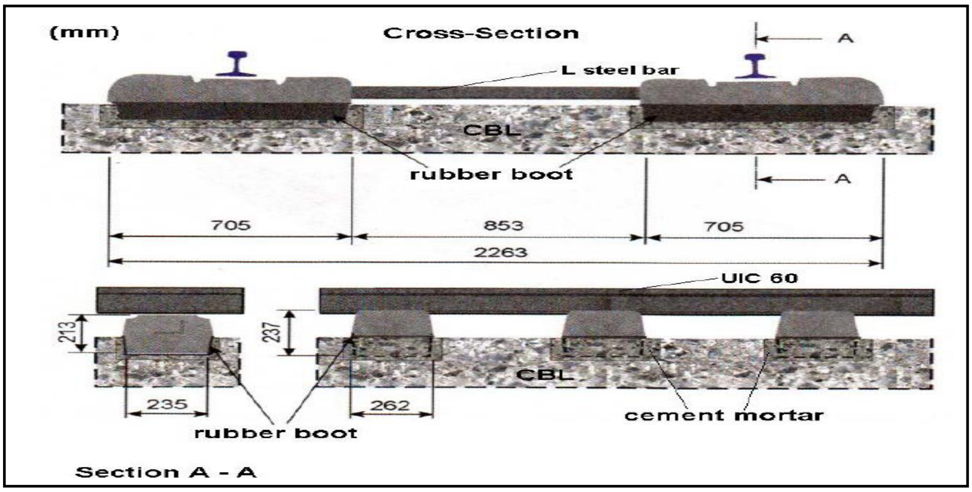

Figure (4) Stedef slab track system

1-1-2-SUPERIMPOSED SLEEPERS

1-1-2-1- GETRAC SYSTEM

Getrac's Track System is made out of an asphalt basis over which concrete sleepers are placed immediately.

The sleepers are connected to the asphalt layer by special concrete anchor blocks, which carry horizontal stresses from the track to the supporting layer.

This system has an advantage that it can be used with traditional track-laying technology as shown in figure (5).

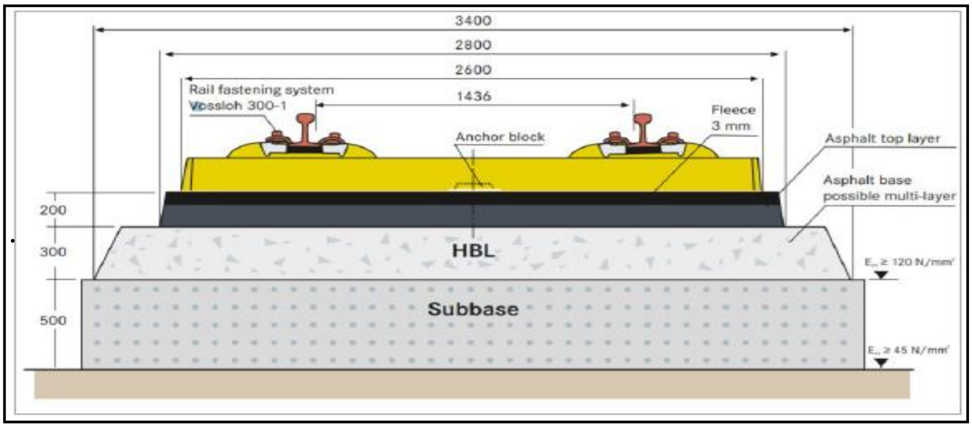

Figure (5) Getrac's Track System [2]

1-1-3-PREFABRICATED SUPPORT WITHOUT SLEEPERS

1-1-3-1- SHINKANSEN SYSTEM

which was used in Japan for its high-speed trains development.

In 1964, its first high-speed railway line across Tokyo and Osaka was completed.

This railway used conventional ballasted track, which caused many problems due to the creation of the Shinkansen Ballastless System [4].

Prefabricated 5m long ballastlesss are put on a concrete surface, with a 4cm thick cement asphalt binder injected below them.

Each ballastless is around 5 ton in weight. One ballastless is 2.34 m wide and 19 cm thick. In both the longitudinal and lateral directions, low pretension is utilised.

A cylindrical stopper, 400-520mm in diameter and 200mm in height, is rigidly coupled with the structural concrete of the foundation between each ballastless to prevent lateral and vertical movement as shown in figure (6) [4], [8], [12].

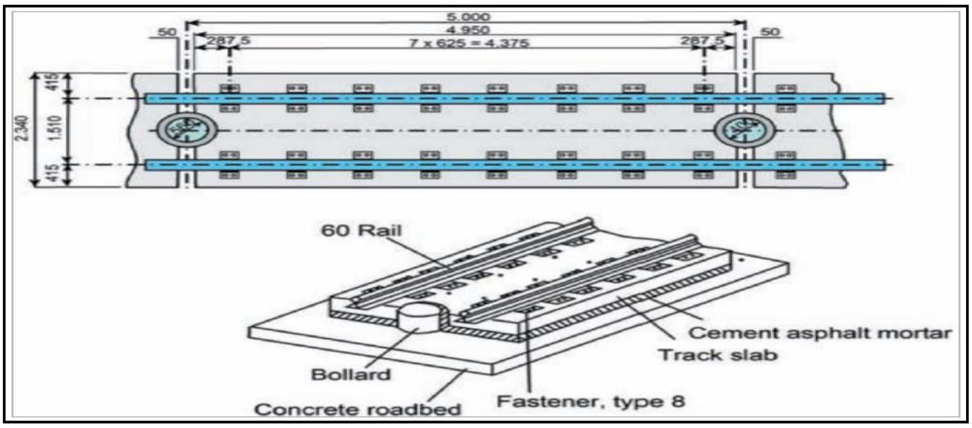

Figure (6) Shinkansen System

1-1-4-MONOLITHIC SUPPORT WITHOUT SLEEPERS

1-1-4-1- PACT-TRACK

A continuous reinforced concrete pavement constructed by a specially designed 'slip-form' paver is known as Paved Concrete Track (PACT).

It has a 2.43 m wide, 22.9 cm thickness.

A modified slip-form paving machine was utilized to construct the concrete [9].

The inexpensive construction costs and high-quality geometry are two of the system's advantages.

This is particularly helpful in existing main line tunnels, where the lower construction depth could allow for improved overhead clearance for 25 kV electricity or the passage of huge container trains.

Drainage channels need to be given a lot of care with this track system.

The accumulation of dirt in the drainage system leads to corrosion of railway fastenings as shown in figure (7) [12], [13].

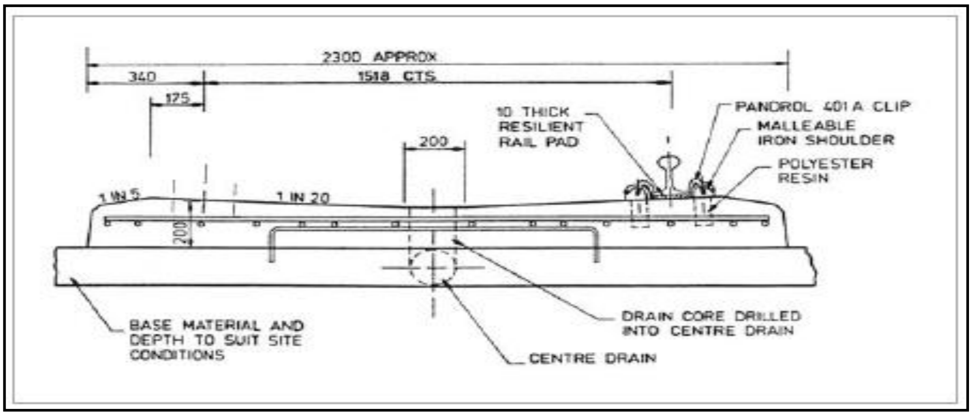

Figure (7) Pact Track System

1-2- CONTINUOUSE RAIL SUPPORT

1-2-1- EMBEDDED CONTINUOUS RAIL SUPPORT

1-2-1-1- INFUNDO-EDILON SYSTEM

The INFUNDO and EDILON concepts are of the same type, with the same construction principles and attributes.

The INFUNDO is a continuation of the Dutch Edilon model.

This technology was first created in the Netherlands in the 1970s (1976, near Deurne, on a testing track capable of speeds of up to 160 km), and it is still being developed today. Elastic materials in a groove support a continuous rail indefinitely.

A slip - form paver is used to lay a concrete supporting layer.

This layer is 40 centimeter’s deep and 2.4 meters long. As shown in next figure.

The construction beneath the concrete supporting layer is kept same (HBL and FPL underneath the CBL) as it is in most ballastless systems.

INFUNDO is primarily designed for passenger transportation rails (subway system, tramways) as shown in figure (8) [14].

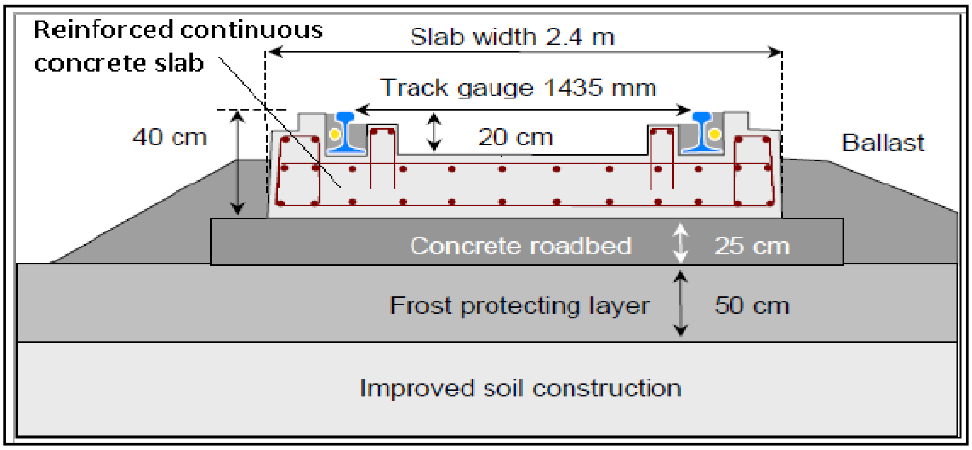

Figure (8) INFUNDO-EDILON Track System

1-2-2- CONTINUOUSLY AND CLAMPED SUPPORT

1-2-2-1- GROOVED RAIL SYSTEM

Phoenix invented this track system, which is a constantly supported grooved rail (ERL) used primarily for tramways.

It is made up of an elastically flexible rail that can be fastened even without rail fasteners.

A rubber strip having air chambers serves as an elastic support below the rail.

To reduce noise emissions and serve as a transitional between the rail as well as the road asphalt, the rail is wrapped in special rubber chambers.

To secure its track gauge, a high-grade concrete supporting layer (CBL) gives support to the both rails on it, which are attached to each other through steel bars as shown in figure (9).

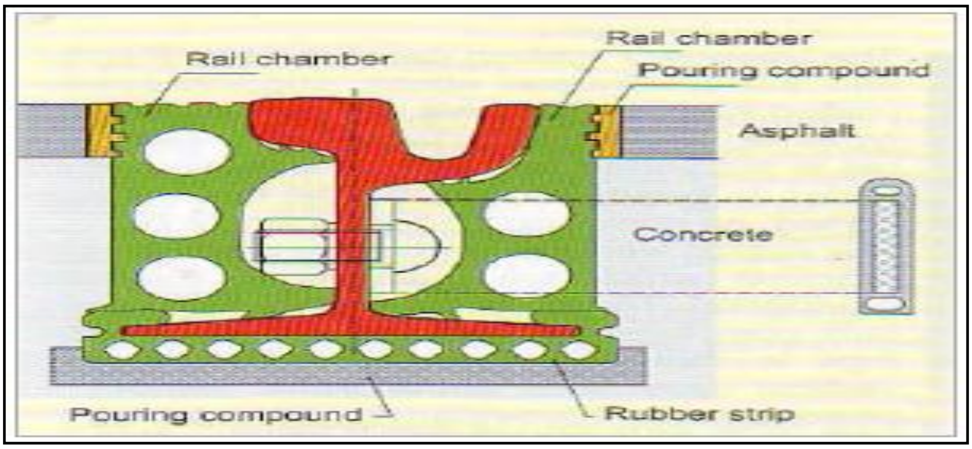

Figure (9) ERL Track System

2- COMPARISON OF BALLASTLESS TRACK FOR DIFFERENT SYSTEMS

The following items would be taken to compare between the different ballastless techniques as shown in table (1) as follows:

1- The total height
2- The Maximum allowable speeds it could support
3- The noise emission
4- Construction Costs
5- Construction period
6- Easy renewal

These above- mentioned factors have a great effect on the choice of the best ballastless design.

Table (1) summarizes all of these variables.

The following numbers were used in the 'Noise assessment & Renewal assessment' columns:

I = recommended,

II = satisfactory,

And III = needs to be improved.

The ‘H’ column refers to is the height of the superstructure from the upper edge of the rail to the bottom of the hydraulically bonded layer (HBL).

The 'cost' column refers to manufacturing costs from the HBL's upper edge, The tunnel sole, or the bridge's substructure,

The 'daily performance' column denotes the length of track to be built in an 8-hour shift.

Table (1) Different ballastless track design are compared in terms of both technical and economic aspects [2], [5], [15], [16], [17]

Ballastless track type	Ballastless Track System	System name	H (mm)	V (km/h)	Noise assessment	Cost (€/m)	Daily performance (m)	Renewal assessment
Discrete rail support with sleepers	Sleepers Embedded in Concrete	Rheda Classic	931	300	II	1198	172	III
		Rheda-Berlin	951	300	III	630	170	III
		Zublin	775	300	II	550	200	II
		Stedef (used in ground Cairo metro)	775	100	II	-	-	II
	Sleepers superimposed support	Sato	920	200	II	600	350	I
		Getrac	1008	300	II	625	270	II
Discrete rail support without sleepers	Prefabricated Concrete Slab	Shinkansen	715	200	II	-	200	II
	Monolithic Designs	FFC / PACT	777	300	I	470	200	I
Continuous rail support	Embedded continuous Rail	Infundo-Edilon	650	160	I	470	200	I
	Continuously and clamped Supported Rail	ERL / Saargummi	-	160	II	-	200	II

The numbers were used in the 'Noise assessment & Renewal assessment' columns in the table (1) relate to:

I = recommended,

II = satisfactory,

And III = needs to be improved.

Low flexural stiffness can scarcely resist bending forces, while high flexural stiffness resist bending forces, the following table (2) summarizes the range of flexural stiffness verses the ballastless track systems for the above-mentioned classification [2], [18].

Table (2) Approximate flexural stiffness of the superstructure for different ballastless track systems [2]

Ballastless track type	Ballastless Track System	Flexural Stiffness	
		Low	High
Discrete rail support with sleepers	Sleepers Embedded in Concrete	←——	——→
	Sleepers superimposed support	←→	
Discrete rail support without sleepers	Prefabricated Concrete Slab	←——	—→
	Monolithic Designs	←——	——→
Continuous rail support	Embedded continuous Rail	←——	———→
	Continuously and clamped Supported Rail	←——	——→

3- EVALUATION AND RECOMMENDATIONS

According to the previous comparison, one can arrange the types of ballastless tracks according to each different aspect as followings:

The following numbers were used in the 'evaluation' columns:

I = recommended,
II = satisfactory,
III= needs to be improved:

Tables from (3) to (9) summarize the main conclusions and the useful recommendations.

- Flexural Stiffness: "Which expresses the appropriate system in the case of heavy loads"

Table (3) Evaluation of different ballastless tracks according to flexural stiffness aspect

Flexural Stiffness	
Evaluation	Ballastless Track System
I	Embedded Rail
II	Sleepers Embedded in Concrete
	Monolithic Designs
	Continuously and clamped Supported Rail
	Prefabricated Concrete Slab
III	Sleepers Superimposed suport

- Overall height: "Which expresses the appropriate system in tunnels or limited heights"

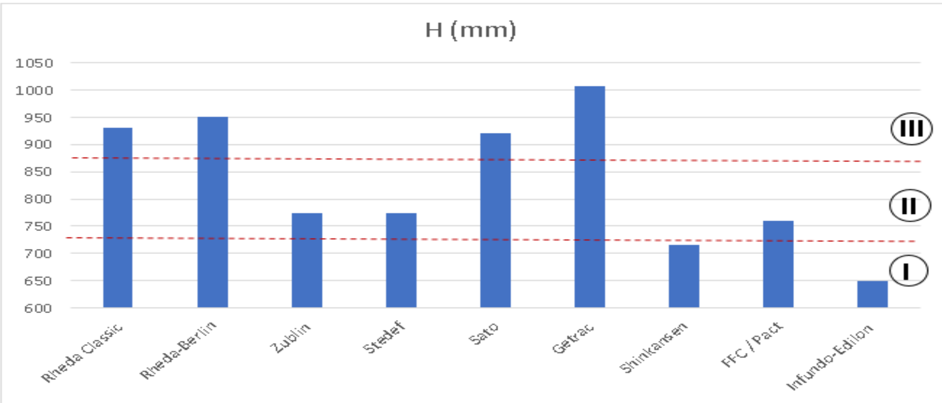

Figure (10) overall height of different ballastless tracks

Table (4) Evaluation of different ballastless tracks according to overall height

Overall height (H)	
Evaluation	Ballastless Track System
I	Embedded Continuous Rail
	Prefabricated Concrete Slab
II	Sleepers Embedded in Concrete
	Monolithic Designs
	Continuously and clamped Supported Rail
III	Sleepers Superimposed suport

- Velocity: "Which expresses the appropriate system in long distances"

Table (5) Evaluation of different ballastless tracks according to velocity

Velocity	
Evaluation	Ballastless Track System
I	Sleepers Embedded in Concrete
	Monolithic Designs
II	Sleepers Superimposed suport
	Prefabricated Concrete Slab
III	Embedded Continuous Rail
	Continuously and clamped Supported Rail

- Noise: "Which expresses the appropriate system within the residential areas"

Table (6) Evaluation of different ballastless tracks according to noise

Noise assessment	
Evaluation	Ballastless Track System
I	Embedded Continuous Rail
	Monolithic Designs
II	Prefabricated Concrete Slab
	Continuously and clamped Supported Rail
	Sleepers Superimposed suport
III	Sleepers Embedded in Concrete

- Cost: "Which expresses the most economical system to be constructed"

Table (7) Evaluation of different ballastless tracks according to construction Cost

Cost	
Evaluation	Ballastless Track System
I	Embedded Continuous Rail
	Monolithic Designs
II	Sleepers Superimposed suport
	Continuously and clamped Supported Rail
	Prefabricated Concrete Slab
III	Sleepers Embedded in Concrete

- Daily Performance: "Which expresses the fastest system to be constructed"

Table (8) Evaluation of different ballastless tracks according to construction period

Daily Performance	
Evaluation	Ballastless Track System
I	Sleepers Superimposed suport
II	Embedded Continuous Rail
	Monolithic Designs
	Prefabricated Concrete Slab
	Continuously and clamped Supported Rail
III	Sleepers Embedded in Concrete

- Renewal assessment: "Which expresses the most durability system"

Table (9) Evaluation of different ballastless tracks according to the need for repairs and periodic maintenance

Renewal assessment	
Evaluation	Ballastless Track System
I	Embedded Continuous Rail
	Monolithic Designs
II	Sleepers Superimposed suport
	Prefabricated Concrete Slab
	Continuously and clamped Supported Rail
III	Sleepers Embedded in Concrete

The following table (10) shows a summary of the evaluation according to the previse aspects.

Table (10) Summary of total evaluation

Ballastless Track Type	Ballastless Track System	Flexural Stiffness	H	V	Noise assessment	Cost	Daily performance	Renewal assessment
Discrete rail support with sleepers	Sleepers Embedded in Concrete	II	II	I	III	III	III	III
	Sleepers Superimposed suport	III	III	II	II	II	I	II
Discrete rail support without sleepers	Prefabricated Concrete Slab	II	I	II	II	II	II	II
	Monolithic Designs	II	II	I	I	I	II	I
Continuous rail suport	Embedded Continuous Rail	I	I	III	I	I	II	I
	Continuously and clamped Supported Rail	II	II	III	II	II	II	II

4- CONCLUSIONS

- The progression of railway transport has increased the need for high speed trains, in order to be able to keep up with the requirements, different types of railway track systems beside conventional ballasted system has appeared.
- Modern systems tend more and more towards the ballastless track, so it easily deduces the suitable ballastless system according to the previous evaluation which can symmetries as follows:
    1- Embedded continuous rail system is considered the highest rated system compared to the rest of the systems,
    2- Followed by the monolithic system.
    3- Embedded continuous rail system and monolithic system considered as the latest systems that were used in the late nineties.

5- Sleepers embedded in concrete comes at the bottom of the list that System considered as the first type of ballastless systems which appeared in the seventies, and after that, the developments that took place on the ballastless system continued.

REFERENCES

[1] N. Avramovic, "Comparison of Ballast and Ballastless Tracks," no. April, 2010.

[2] E. G. Oral, "COMPARISON OF BALLASTED AND SLAB TRACK BASED ON LCC ANALYSIS," no. A.y., 2020.

[3] H. Lund, "Transition zones between ballasted and ballastless tracks," no., 2014.

[4] C. Esveld, "Recent developments in slab track, " Delf, 2003.

[5] B. Lichtberger, Track Compendium: Track System, Substructure, Maintenance, Economics, Eurail Press, 2005.

[6] M. Budisa, Advanced Track Design, USA.

[7] J. S. Nandhini M., "Design of Hydraulic Bound Layer for Ballastless Track," Journal of Chemical and Pharmaceutical Sciences, vol. 9, no. 3, 2016.

[8] Björkquist, W., & Janjua, I."Evaluation and comparison of ballastless tracksystems with regards to system andperformance characteristics," no., 2020.

[9] R. GmbH, "www.railone.com," April 2011, [Online]. Available: https://www.railone.com/fileadmin/daten/05-presse-medien/downloads/broschueren/en/Rheda2000_EN_2011_ebook.pdf.

[10] Railone, "Rheda 2000 Ballastless Track System," [Online]. Available: https://www.railone.com/.

[11] G. Michas, "Slab Track Systems for High-Speed Railways," no., 2012.

[12] H. S. L. Y. B. K. E. K. W. L. Y. S. K. S. Y. Jang, "Development of Prefabricated Concrete Slab Track Systems and Trial Installation on Revenue Line," Korea Railroad Research Institute, Seoul.

[13] C. F. Bonnett, Practical Railway Engineering 2nd edition, Imperial College Press, 2005.

[14] P. S. a. G. M. R. P. David N. Bilow, "SLAB TRACK FOR THE NEXT 100 YEARS," Portland Cement Association, Skokie, IL.

[15] Zeng, Z. P., Xiao, Y. C., Wang, W. D., Huang, X. D., Du, X. G., Liu, L. L., ... & Wang, J. D. "The Influence of Track Structure Parameters on the Dynamic Response Sensitivity of Heavy Haul Train-LVT System" no., 2021.

[16] Le Pen L, Milne D, Thompson D, Powrie W "Evaluating railway track support stiffness from trackside measurements in the absence of wheel load data." no., 2016.

[17] P. Veit, "The Economic Service Life of Track," Graz University of Technology, Graz,, 2016.

[18] J. Šestakova, "Quality of Slab Track Construction – Track Aligment Design and Track Geometry," De Gruyter, Žilina, 2015.