TAIWAN TRACKWORK DEVELOPMENT
– NONBALLAST TRACK SYSTEM –

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Abstract

The railway system with its high capacity, low energy consumption, comfort and punctuality now is the main stream of the inland transportation system around the world. The high cost and heavy load of the maintenance work of the traditional ballast track system have attracting the attention of the recent studies. The results of the research have come to a common conclusion that in the future the ballast track system will be replaced by the non-ballast track system.

This paper elucidates the development history of the non-ballast track in the local railway system including Taiwan Railway Administration Bureau (TRA), Mass Rapid Transit System (MRT), High Speed Railway (HSR) and Light Rail System (LR), etc. The trend of future development of these systems under the influence of world-wide development of non-ballast system as well as the characteristics of the local area and technical capability of the existing system are also discussed in this paper. The recommendations and suggestions are proposed as references for the research work and real practice of the domestic and international railway industry.

1. PREFACE

The construction the inland transportation system of Taiwan is concentrated on the highway and railway system, the previous development and current situation of the inland transportation system will be illustrated as follows.

In the recent years, the construction of the road could never cope with the growth of the vehicle, the high population density and shortage of the area for the construction of road make the situation even worse. The traffic congestion due to the above reasons is almost beyond the tolerance limit of the people. So railway system which could carry huge amount of people at the same time is coming back as the main stream of the inland transportation of Taiwan. . Punctuality, fixed travelling time and high safety of the railway system which are appreciated by the people make the railway system flourish again. Extensive research work on the planning, design, construction and operation of the railway system such as Mass Transit System, Inter-City High Speed Railway, Light Rail, etc. have been done in the past few years. And at the same time Taiwan Railway Administration Bureau (TRA) is in the process to renew their facilities.

The engineering aspects of the railway system in Taiwan area will be illustrated as follows:

From the traditional dual-purpose railway (Taiwan Railway Administration Bureau) for passenger and cargo, to the Taipei MRT system, and Taiwan High Speed Rail or light rail, the basic theorems and technique are similar, but the design, construction, operation and maintenance are not the same due to different demands and time frame. In consideration of the WTO, the internationalization of the local market and the shortage of the financial resources, the execution of the important railway project could be on BOT basis. The construction of the future railway system could be a joint venture of the local contractors together with foreign contractors, so a clear understanding of the development and trend of the international rail industry is very important for the local contractors.

The international railway society has been long devoted to the research work of a higher safety and lower maintenance railway system. The non-ballast track system is the focus of the studies, because it could meet the above-mentioned requirements. The railway industry in Taiwan has already acquired substantial experiences on the non-ballast track system and part the experiences should be shared with the international railway community. This study will illustrate and analyze the past and current situation as well as the future development of the non-ballast track system in Taiwan.

2. RAIL TYPES OF THE LOCAL RAILWAY SYSTEM

2.1 Taiwan Railway Administration Bureau (TRA)

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Taiwan Railway Administration Bureau has accumulated more than a hundred years of experiences on the maintenance and operation of railway system. TRA now is facing the same problem as other railway systems – "the amount of the routine maintenance and operation cost are increasing and the profit is eroding away due to the heavy expenditure". In consideration of such situation, TRA introduced the Japanese slab type non-ballast track system during the construction of the Nan-Kang bridge in 1993 and English slab type non-ballast track system which is adopted in Taipei MRT system during the construction of the Miao-Nan tunnel. At grade ballastless track was incorporated in the construction of the railway from Chung-Hwa to Chui-Fen in the year of 1999.

2.2 The East Railway Re-Construction Bureau (ERRB)

The Eastern Railway Re-Construction Bureau adopts the traditional ballast-bed railway system as the main railway system. In consideration of the world trend-"the adoption of low maintenance and low capital investment non-ballast track system", ERRB issued the tender for the design and construction of the non-ballast track system in the year of 1999 and the tender has already successfully awarded.

2.3 Mass Rapid Transit System

The first mass transit system of Taiwan is the Taipei MRT system. In the early stage of the planning work, the general consultant BMTC adopted the non-ballast track in the elevated bridge and tunnel sections; traditional ballast track was selected for the surface sections. The succeeding general consultant ATC followed the same idea without any modifications. The final decision is the concrete track plinth currently used on the mainline of the Taipei MRT system, in the special trackwork area, English type slab track is adopted.

2.4 The North-South High Speed Railway

The planning work of the high-speed railway was initiated in the year of 1990, within the past ten years, the project has been shifted from a traditional government public work to a BOT project. The China High-Speed Railway Company and The Taiwan High-Speed Railway Company are the two competitors for this BOT project; these two parties adopted Japanese high-speed railway system and the European high-speed Railway system respectively. In the year of 1998, the BOT project was awarded to Taiwan High-Speed Railway Company. The company then started the financial arrangement and commenced the work for the planning, design and construction of the first high-speed railway in Taiwan.

- Temporary Office in the year of 1990
  The ballast track-bed was adopted for the most area in mainline and non-ballast track was selected for part of the tunnel sections in mainline. UIC 60 rail was selected for the mainline, UIC50 rail was selected for the depot.
- During the Tendering Stage
  China High-Speed Railway Co. selected the Japanese system so Japanese slab track-bed is adopted as the track system.
  Taiwan High-Speed Railway Co. selected the European combined system so traditional wood or concrete sleeper (stedef) were selected as the track system.
- Taiwan High-Speed Railway Company
  Up to the present date (March 8, 2000), after evaluation on the two systems, Taiwan High-Speed Railway shifts from the European system to Japanese system, and the priority for negotiation is given to the Japanese company.

2.5 Light-Rail System

There is no light-rail system in Taiwan; the future development of the local system will be analyzed in the text on the illustration of foreign light-rail system.

3. TAIWAN RAIL WAY ADMINISTRATION BUREAU

3.1 Nan-Kang River Bridge (1993)

In the year 1992, the Japanese slab roadbed track system was adopted for the sections between Chu-Nan and Tsao-Chiao of Taichung Line; the work was complete in 1993. The details of the work are listed as follows:

3.1.1 General Description

- Special Requirements
  Plane radius R=820 m, C=95mm. The total length of curve section is 827.054 m and the slope of 115m out of the total curve sections should be 0%.
- Design speed = 120 km/h
- Rail gauge = 1067 mm

3.1.2 Japanese A-155 Slab Track

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- There are five different types of concrete bases, namely, A, B, C, D and E. the length of concrete base is 5 meter. The concrete bases are laid in jumping intervals. 400mm & anti-sliding cylinder is installed between the bases to absorb the rail axial force.
- After the concrete strength of the precasted slab is more than 400 kg/cm^2, it will be shipped to the construction site for installation. The distance between the slabs is 7 cm; asphalt emulsion cement mortar is injected into the space between the slabs and the concrete bases (the gap about 5cm) after the slabs are fixed on the designated positions.
- The asphalt emulsion cement mortar is semi rigid mortar made of asphalt emulsion, water, cement, fine aggregates and various kinds of admixtures. The main purpose of the mortar is to provide an alternative trackbed with sufficient elasticity to absorb the construction deviation and settlement. The strength of the mortar is 10 kg/cm^2 (for slab base) and 25 kg/cm^2 (for anti-sliding block). The elasticity modulus is 125kg/cm^3. The water content affects the strength of the mortar and the temperature affects the workability, so test of the water content should be carried out prior to the construction and the flow time should be controlled to be in the range of 16-26 seconds.

3.2 Miao-Nan Tunnel (1998)

In 1996 TRA had an open tender for the design and construction of the installation of the elastic baseplate concrete slab track of the Miao-Nan tunnel of the mountain line. The work was completed in 1998.

3.2.1 General Description

A. Characteristics of the Project
   - The work items include the installation of the elastic baseplate concrete slab track and base concrete
   - The design speed = 130 km/h
   - The rail should be KS18 and 50N long welding rail
   - The total passing tonnage of the train is 20 million tons per year
   - The insulation impedance of rail is 0.5 million ohm and the leakage impedance between the rails is 1 ohm/km
   - The 28 day compression strength of the concrete should be no less than 400 kg/cm^2
   - The concrete beneath the rail fasteners should be smooth and levelling, the voids ratio should not exceed 2% of base slab area, and the maximum void should not exceed 3 mm, over it should be covered with epoxy.
   - Expansion joint with a width 3±0.1 cm should be installed every 50 meter (or less then 50 meter) of track concrete and base concrete.
   - The rail fastener device should be able to resist 3 ton pulling force from both sides of the rail and withheld 7 ton breaking force

B. Allowable Static Geometric Tolerance of the Rail for Final Acceptance
   - Rail Gauge: 0,-3mm
   - Horizontal : 2mm
   - Elevation : 2mm/10m
   - Direction : 2mm/10m
   - Plane : 4 mm (not including cant decrease)

C. Clouth elastic baseplate and top down construction method were adopted for the final construction of the concrete slab trackwork.

3.3 AT Grade Ballastless Track (1999)

In 1999 TRA had an open tender for the design and construction of the installation of the At Grade Ballastless Track between Chui-Fen and Chung-Hwa of the mainline. The work was successfully awarded to the contractor at the same year.

Since this project is still under construction, so this paper will make description on the general condition and design codes only.

3.3.1 General Condition

- TRA provides 256 pieces of 25 meters long UIC60 rail
- The track to be built in this project is Hai-Si line, and 4 meter apart from the Hai-Si line, there lies the Hai-Tong line currently still in operation. The contractor should be responsible for the alignment of the new track line and in consideration of the safety, strength and economic conditions to construct the at grade ballastless track for Hai-Si line following the same design standard as Hai-tong line.
- The rail gauge for the at grade ballastless track is 1067 mm

3.3.2 Engineering Characteristics

- Design live load :KS18
- Design speed : 130 km/h
- The total passing tonnage of the train is 20 million ton per year
- Impedance of the Rail : no less than 0.5 MΩ
- Leakage Impedance Between Rails : no less than

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1 Ω/km

- ♦ The design of the ballastless track should take into consideration of the conduit for the passage of 110 mm ∮ cable. The surface of the track should be smooth without voids.
- ♦ The trackbed of the ballast track should be sound and durable under the cycle loading and the settlement should be controlled to the minimum. (Permeability $< 10^{6}$ m/s)
- ♦ The longitudinal drainage slope should not be less than 0.3%, and the transverse drainage should connect to the side ditch.
- ♦ Interface between the flexible and rigid trackbed should use transition device.

TRA has the plan to replace the existing traditional ballast track with non-ballast track from Chung-Hwa to Tainan starting from the year 2000. The purpose of the replacing operation is to reduce the long-term maintenance cost and increase the train speed to 130 km/h.

The future research work of TRA will concentrate on the maintenance-free non-ballast track and increase the train speed to 160 km/h.

4. EAST RAILWAY RE-CONSTRUCTION BUREAU

4.1 Tendering of the non-ballast track in 1999

In 1999 East Railway Re-Construction Bureau (ERRB) had an open tender for the installation of the non-ballast anti-vibration track between Ho-Ping to Chung-Teh of the North Loop Line. The work was successfully awarded to the contractor at the same year. Since this project is still under construction, so this paper will make description on the general conditions of the tender document only.

Design Conditions:

- ♦ The Owner provides 25 meter long fixed length 50N rail
- ♦ KS18 standard live load is adopted as the design loading
- ♦ Highest speed of the train is above 130 km/h
- ♦ Compression strength of the concrete fc'=350 kg/cm^2
- ♦ The spring constant of the elastic material should be 20-30 tf/cm with a design life of more than 20 years. The rubber pad beneath the rail should conform to TRA standard specifications
- ♦ Simple structure, easy construction should be observed and all the material should be in compatible with the material currently used by TRA

4.2 Trend of Future Development

Nonballast track system will be the focus of the future study of ERRB and the experiences obtained form the construction of the nonballast track between Ho-Ping and Chung-Teh are very valuable for the future development.

5. Mass Rapid Transit System

5.1 Introduction

5.1.1 The composition of the Taipei MRT system

The non-ballast track system of the Taipei MRT is composed of three major components, namely, the rail, rail fastener and track support system. The material and their respective functions will be illustrated as follows:

A. Material

- ♦ Rail
  UIC60 rail specified in the UIC specification is adopted; the related requirements could be referred to UIC860 or U.S.A. AREA code.
- ♦ Track Support system
  The track support of the non-ballast track system could be divided into the one for special track area and the other track plinth used for the mainline. The material is cast-in-place concrete. Special consideration is given to the prevention of electricity stray current. The embedded components of the track support system should have certain degree of insulation to meet the requirement to prevent random electricity current. Synthetic plastic is adopted as the material for the anchor insert for the support of the conductor rail. To meet the requirement that the rail to ground impedance should not be less than 10MΩ/m. Channels and connecting dowels should be reserved for the connecting of the track support and the civil structure and to withheld the longitudinal sliding force and shear between these two types of structures.

B. Function

- ♦ Rail
  All the rails of the Taipei MRT are welded together as a single structure, so it is a joint less continuous welding rail.
- ♦ Rail Fastener
  The rail fastener of the non-ballast track is a highly specialized technique; the three major components of the fastener are as follows:
  - ➢ Spring clip, clip insulator
  - ➢ Spring sandwich plate, rail pad, rail baseplate
  - ➢ Anchor component: embedded anchor insert, anchor bolt

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♦ Track Support System

The power supply of Taipei MRT is through the conduct rail, so the basic functions of the track support system are as follows:

- Enough strength to support the rail
- Confine the settlement of the rail in an acceptable range
- Easy construction and maintenance-free
- Long service life
- Good electricity insulation
- Good resistance to environmental erosion
- to absorb the vibration and noise
- High construction accuracy
- Economic

5.1.2 The guideline for the selection of the trackbed system

The table used for the selection of the two types of the track-bed for the Taipei MRT system is shown on the following table. Based on the evaluation result shown on the table, traditional ballast track is selected for the ground sections and depot, non-ballast system is used for the elevated and tunnel sections.

Factor for evaluation	Preference	
	Ballast track	Non-ballast track
1.minimum maintenance work		✓
2.minimum weight of the civil structure		✓
3.easy drainage system		✓
4.maintain of the permanent track line and level		✓
5.easy fixation of the third rail		✓
6.minimum damage during de-rail	✓	
7.absorption of the unequal settlement	✓	
8.noise and vibration reduction effect	✓	
9.future modification of the alignment	✓	
10.guarantee of the construction quality	✓	
11.intrusion of the ground water	✓	
12.construction cost	✓	
13.fast maintenance within short interval	✓	

5.2 Experiences

5.2.1 Tam-shui line

- ♦ The design of the non-ballast track for the elevated sections should be incorporated with the design of the civil structure.
- ♦ Workability of the concrete for the non-ballast track should be taken into consideration during the mix design.
- ♦ The sequences for the installation of the rail should be carefully observed to prevent the damage of the baseplate
- ♦ The concreting work of the non-ballast track should be done by automatic machine with high accuracy

5.2.2 Hsin-Chung Line

- ♦ Hsin-Chung line is full of tunnel; the delivery of the material and construction equipment should be carefully arranged in advance, especially the concreting work.
- ♦ The construction of non-ballast track is a difficult and time-consuming work, so a well understanding of the civil work is a necessity to have smooth progress of the work.

5.2.3 Nan-Pan Line

Non-ballast track is difficult for the inspection and the construction under the adverse working condition, so an well-organized planning work is vital to the success of the project.

5.2.4 Tu-Chen Line

The specification for final finishing of the concrete work of the non-ballast track should be adjusted according to the local working condition and engineering practices. Alternatives brought out by the contractor should be allowed.

5.3 Direction for Future Development

The noise-absorption and vibration-reduction could be the focus of the future study; generally speaking, these two issues could be taken care by the following measures.

5.3.1 Rail fastener of the non-ballast track

- ♦ The insert loss of the rail fastener of non-ballast track
- ♦ Prevention of the resonance between the fastener and rail, civil work, car body etc.
- ♦ Proper stiffness and damping factor

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5.3.2 Elastic trackbed

There are many types of elastic trackbed, such as Stedef sleeper, elastic support pads, floating slab, etc. the floating slab will be illustrated as follows:

There are two types of floating slabs, mechanic type and elastic type, the guideline for the selection of the floating slab are as follows:

- ♦ The compatibility between the available space of the civil structures and the space needed for the floating slab
- ♦ The anticipated absorption value of the noise volume and the particular frequency
- ♦ The economic evalution within its service life
- ♦ Resonance should be prevented in the case that both the floating slab and non-ballast fastener are adopted
- ♦ The space and percentage of automation needed for the construction equipment
- ♦ The daily maintenance time and its impact to the daily operation

6. N-S HIGH SPEED RAILWAY

6.1 Temporary Office for the High-Speed Railway

In the early stage of the planning work of high-speed railway, the European system was favored, and lots study had been concentrated on the types of the trackbed. The final decision is the long welding rail with expansion joints, which is adopted by the European system.

6.2 High-Speed Railway Bureau

During the period from 3/01/1996 to 7/31/1997, Deutsche Eisenbahn – Consulting Gmbh and SYSTRA-SOFRETU-SOFREAIL were retained by HSRB to compile the planning manual for the track work in the basic design report. The abstracts of the planning manual are as follows:

- ♦ Types of the trackbed
  - ➢ Ballast trackbed will be adopted for the ground and elevated sections, while water- proof layer and surface protection layer or ballast mat should be installed for the elevated sections
  - ➢ Slab trackbed should be adopted for the tunnel sections
- ♦ There are three different grades of tracks
  - ➢ For the mainline with speed higher than 160 km/h
  - ➢ For the mainline with speed lower than 160 km/h
  - ➢ For other area with speed lower than 60 km/h, such as siding and depot
- ♦ The specification of the non-ballast trackbed
  - ➢ Track gauge = 1435 mm
  - ➢ Inclination of the rail could be 1:40 or 1:20
  - ➢ The turnout (switch and crossing) and expansion joint should be installed on the Slab trackbed
  - ➢ The vertical elastic deformation of rail should be controlled in range from 1.0 to 1.5 mm under the axial load of 200 kn
  - ➢ The Slab trackbed is composed of the sleeper embedded into the concrete slab
  - ➢ The sub-structure of the trackbed should be free from settlement, such as elevated bridge or tunnel
  - ➢ The tolerance of the concrete deviation for the slab trackbed should be controlled to be less than 10 mm for elevation and ±1 mm direction adjustable allowance for the fastener device should reserved
  - ➢ Should slab trackbed be on top of the asphalt layer in the tunnel section, the minimum thickness of the asphalt should not be less than 250 mm

6.3 Taiwan High-Speed Railway Company (THSRC)

After further evaluation on the European combined system and Japanese system, THSRC has decided to give the priority for negotiation to the Japanese system. Should the Japanese system fail to reach agreement with THSRC, the European combined system still has the chance to participate in the negotiation. THSRC is more flexible now on the selection of the system. Since the track system is not yet decided at this moment, only the safety considerations of the track system will illustrated as follows:

- ♦ Analysis on the impact of the train load to the structure
- ♦ Impact to the rail due to thermal variation
- ♦ Operation aspects of the railway system
- ♦ De-rail prevention measures
- ♦ Good drainage system
- ♦ Noise and vibration prevention
- ♦ Test and examination of the rail in accordance with UIC 860-0
- ♦ Ballast should be granular with sharp edges and free from chemical components
- ♦ Non-ballast track should be equipped with adjustable device and suitable noise and vibration prevention design

7. LIGHT RAIL SYSTEM

Currently, there is no light rail system under

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design or construction in Taiwan, so only the foreign light rail system will be discussed. There are two types of light rails, the general type and streetcar type. The characteristics of modern light rail is similar to the traditional railway, high-speed railway and MRT system, so the factors considered in the selection of the trackbed system are also similar, so it is recommended that the future light rail in Taiwan should adopt the non-ballast track system.

8. THE FUTURE OF NON-BALLAST TRACK SYSTEM IN TAIWAN

Non-ballast track system will become the mainstream of the railway system in Taiwan; the functional requirements and the evaluation items for the future development of the non-ballast track system are illustrated as follows:

8.1 Functional requirements of the non-ballast track system

- Sufficient strength to satisfy the loading condition
- Stability to meet the operational requirements
- Enough durability of the material
- Good electricity insulation and resistance to environmental erosion
- Without damge under certain situation of structure deformation
- Capability of noise absorption, vibration reduction and proper spring coefficient
- Automation of the construction equipment
- Easy construction and maintenance
- Confine the track displacement to an allowable range
- High economic evaluation within the service life

8.2 Evaluation Items Of The Non-Ballast Track System

- Design Loading
- Design Speed
- Track confine Force
- Displacement Of The Rail
- Spring coefficient
- Noise Absorption And Vibration Reduction
- Resonance Between The Car And Structure
- Electricity Insulation
- Degree Of Automation
- Easy Construction
- Time And Convenience Of Maintenance Work
- Anti-Corrosion
- Test Plan
- Economic Evaluation

9. CONCLUSION

It is obvious that the non-ballast track system will be the mainstream of the future railway system. Every country has her particular non-ballast system to meet the local demands, such as the concrete plinth of the U.S., Stedef sleeper of France, embedded sleeper of Germany, slab trackbed of U.K. and Japan, etc. It clearly indicates that there is no universal non-ballast track system acceptable to everybody. It is very difficult to integrate the various systems into one unique system. If the other parties could share the experiences of each individual system and the knowledge could be spread among the international community, the level of the technology and service of the railway will certainly be escalated.

This paper makes a deeply discussion on the flourishing development of the railway industry in Taiwan. Taiwan has attracted the attention and essences of various kinds of railway technology, from high-speed railway, traditional railway, MRT and light rail system. The new technology and ideas absorbed should be further utilized and integrated into a standard non-ballast track system specially tailored for the local demands. This knowledge could also be a good reference for the international rail industry. This paper elucidates the current utilization of non-ballast track and its future development in Taiwan. Recommendations on the evaluation of the non-ballast track system are also brought out as the basis for the selection the most suitable non-ballast track system for the different railway systems in Taiwan area.

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