Trackwork innovation: Non-ballasted track in Taiwan

Kuo H. Cheng , Relon J.T. Chen , Sy. Chang , Kai-Chieh Chia
*Director, East District Project Office of DORTS, T.C.G.*
*Vice President, China Engineering Consultants, Inc.*
*Senior Engineer, China Engineering Consultants, Inc.*
*Research Specialist, Institute of Transportation, MOTC*

**Abstract**

Due to its high capacity, low energy consumption, comfort and punctuality, the railway system has become the main stream of inland transportation in the world. And now accordingly with the results of recent studies and research, it has become clear that in the future the ballast track railway system will eventually be replaced by the non-ballast track railway system.

In Taiwan, the subject of mass rapid transit non-ballast track systems has been studied in the practical field for many years now. This particular study presents a simulation of actual cases of operation on a bridge of the Taipei Rapid Transit System (TRTS), and includes the measurements and analysis of in-track loading, the measurements and analysis of track system noise and vibrations, and the EMU and Direct Fixation rail Fastener (DFF) natural frequency and insert loss. The results were examined in order to establish the direct fixation rail fastener testing procedure, determine the functional requirements for setting on non-ballast trackbed, and develop a trackbed system evaluation process.

In this paper, we are sharing our experiences and study results for both the design stage and operation stage. Each stage has its own unique characteristics for the designer’s reference, and can help enable the designer to make revisions that will suit the actual conditions. It is our hope that this non-ballast track research will enhance the future development of non-ballast track systems.

**1 Introduction**

With the rapid economic growth of Taiwan and the Asia Pacific Rim, it is patently less than satisfactory to only give attention to the needs of highway
expansion. Since the expansion of highways requires a vast amount of land in restricted and highly populated urban perimeters, and often stimulates the inflow of inhabitants, which repeatedly leads to further traffic volume deterioration and traffic jams, highway transportation remedies cannot solve the traffic congestion issues alone. Therefore, the development and utilization of railway transportation is once again considered to be one of the best approaches and best urban transport tools for handling future transportation endeavors. Furthermore, railway transportation has proven to be successful in terms of its efficiency, cost-effectiveness, punctuality, safety, and customer satisfaction.

In Taiwan, it has become apparent that the construction of a high-capacity railway system is essential to meet the demands of the local people, and a unique plan needs to be implemented for each urban region. Also, since each urban area has its own individual development conditions and particular degree of urgency, the priority of construction has to be assigned by the central government under a rather limited supply of resources and budget. Among these urban areas, the Taipei metropolitan area is on the top of the mass rapid transit system development list. Since the initial planning for the system began in 1984, the Mucha Line, Tamshui Line, Chungho Line, Hsintien Line and part of the Nankang-Panchiao Line have already been completed and put into operation stage-by-stage starting in 1995. In the southern port city of Kaohsiung, the design and construction of a mass rapid transit system for the metropolitan area has been in full swing since 2000 with a BOT concessionaire company, Kaohsiung Rapid Transit Company (KRTC), awarding BOT contracts through the Kaohsiung Mass Rapid Transit (KMRT) Bureau. The system is tentatively scheduled for operation beginning in 2007. And in other urban counties and cities, the process of implementing a preliminary evaluation for a mass rapid or light-rail transit system is under way.

In addition to these urban area systems, an inter-city Taipei-Kaohsiung high-speed rail system is also under construction at this moment in Taiwan. The Taiwan High Speed Rail Corporation (THSR) had been awarded BOT concessionaire contracts from the Bureau of Taiwan High Speed Rail (BOTHSR) Office starting in 1998 for high-speed rail construction, and is now moving into full-phased construction. At the same time, a light rail system is under evaluation in some counties to cope with the construction of a high-speed rail system, and cater to the individual urban development requirements.

The technique of implementing a track system in Taiwan has been improved through a comprehensive search and gathering of information made available worldwide. By focusing on Taiwan's experience with the construction of a resilient rail fastener system on non-ballasted track, and adhering to the global trend of W.T.O., this essay will discuss the structure of specifications for the direct fixation track's rail fasteners, and detail the experiences of non-ballasted track in Taiwan. Thus, this paper can be used as a reference for other researchers to further the development of railways elsewhere in the world.
2 The scope, working process and planning concept of the modern track system

The previous sections have already explained the basic design concept for track components, and the following sections will make further study on direct fixation rail fasteners.

2.1 The planning merits of a modern track system [2] are as follows: (a) Reduction of initial investment cost plus maintenance cost, (b) Handling of necessary functions, (c) Handling of noise and vibration, (d) Handling of rail corrugation.

2.2 The planning process for a modern track system [2] is as follows: (a) Define the objectives and requirements of the track system, (b) Study alternatives of the support system, (c) Attenuate the noise and vibration of the track, (d) Provide adaptability and localization of the bonded base-plate (if necessary), (e) Select and revise the design of the track prototype (localize the track prototype), (f) Carry out the construction operation and feedback process.

2.3 The scope of the planning for a modern track system [2] is as follows: (a) Environmental evaluation, (b) System-wide analysis and definition of the characteristics of the track system, (c) Analysis on wheel and rail interchange and rail deformation, (d) Analysis on the fasteners structure, (e) Economic evaluation at different stages.

3 The Main Requirements for the Design of Direct Fixation Rail Fasteners

The rail and the support system are the upper and lower parts of the track, respectively, while the fastener is an interface element in-between. The design requirements for fasteners are as follows:

3.1 Cost savings: (a) A cost compromise with the concrete bed of plinth is a key related element for fastener design, (b) A fastener has to be suitably selected so that it is in line with the various loading of rolling stocks, (c) To save on the cost, the fastener must ensure the ease of replacement and maintenance.

3.2 Performance: A fastener needs: (a) to have sufficient strength and a reasonable life time, (b) to fix and fasten the rail to resist the vertical / horizontal force and prevent rail creeping, (c) to mitigate and absorb impact and vibration, (d) to allow longitudinal sliding of rail and have enough electrical resistance, (e) to have adjusting alliance of track irregularity and the ability to absorb the different movements between the track and structure.

3.3 To ensure that the special requirements of a fastener are provided, the following elements are needed: (a) A pad to absorb and reduce vibration, (b) A clip to fix the rail and allow the rail to slip under certain force conditions, (c) A compressed pad to resist rail creeping.
4 The study of non-ballasted track testing in Taiwan

Taiwan has already obtained much non-ballasted track experience for several types of trackwork, including trackwork constructed on the slab track of the Taiwan Railway Administration (TRA), the plinth and slab track of the Taipei Rapid Transit System (TRTS), and on concrete sleeper embedded track from the Eastern Railway Re-construction Bureau.

In order to further understand the dynamic behavior of non-ballasted track, the Taipei City Government’s Department of Rapid Transit Systems (DORTS) has launched a series of testing and behavior studies.

4.1 Track dynamic behavior test and survey plan

4.1.1 Taipei Rapid Transit Project

For the Taipei Rapid Transit Project, an actual monitoring plan was conducted on non-ballasted track. By measuring the rail deformation under the same rolling stock running at different loads and various speeds, an effort was made to study the dynamic behavior and compare the results as well as analyze the differences between computer monitoring and actual observations.

In the laboratory, the loading and deformation relation was studied through a series of tests of the load/deformation interrelated on account of the K value on non-ballasted rail base plate. Then, an investigation was made on the dynamic K value at various vehicle speeds through the approach of vertical and lateral load/displacement correction and analysis. The actual load could also be evaluated through the studies of vertical and lateral displacement reduced by actual load and vehicle speed under different K values of moving vehicles (Fig. 1, 2, 3).

Figure 1 vertical loading diagram
Figure 2: the diagram of max. loading in curvature

Figure 3: lateral loading diagram
4.1.2 The design of non-ballasted track bed for the Taichung Railway Underground Project

An example is taken from the Taichung Railway Underground Project using the ABAQUS structural analysis software to proceed with the monitoring and calculation of rail slab structure. It uses the analysis program to ensure the stress and strain due to rolling vehicles on non-ballasted track through the results of static analysis of concrete track bed.

4.1.2.1 Rail gauge 1067 mm, Vehicle speed 130km/hr, Weight of axle 22.6T/axle (S-18) for dynamic state, Weight of axle 18T/axle (K-18) for static state, Vertical force 0.6 D.L., Horizontal impact force 0.1 D.L., Longitudinal force 0.13 D.L., Min. plan alignment 672m, Max. Design super elevation 105 mm, 50kg-N rail, Elastic coefficient stiffness \( k = 25kN/mm \).

4.1.2.2 The rail displacement is analyzed. It was noted that the max. Displacement is \( 4.0436 \times 10^{-4} \)m, max. stress of slab track bed strain analysis is \( 2240kN/m^2 \), and max. Strain is \( 6.9108 \times 10^{-5} \).

The results could assist us in analyzing the rail displacement and stress due to the train moving load on the non-ballasted track bed, and can be utilized to conduct the detailed design of trackwork and review of structure and reinforcing bar installation.

4.1.2.3 A rough estimation of the above analysis implies that the loading is not so significant, and a simple analysis of the base plate can not reflect the actual stress analysis. So, it is suggested to adopt the track dynamic behavior studies of the Taipei Rapid Transit System and Nankang Creek slab track in-situ displacement and stress analysis for further evaluation basis.

Vertical loading test of base plate (DELKOR Formula)

\[
QRW = \frac{Q}{2} \cdot FL \cdot FS \cdot FR \cdot FA \cdot FP
\]

\[
= \frac{22.6}{2} \cdot 0.4 \cdot 1.9 \cdot 1.2 \cdot 1 \cdot 1
\]

\[
= 10.31
\]

\[
= 10t = 9.8KN
\]

\( QRW \): The effective wheel weight of bearing point of each rail

\( Q \): The wheel weight 22.6t

\( FL \): The appropriate elastic bearing of wheel distribution coefficient 0.4

(0.4 for DELKOR and 0.38 for LORD, both close to 0.4)

\( FS = 1 + t \cdot RH0 \cdot PHI \)

\( t = 1 \) for low safety coefficient concern
\( t = 2 \) for medium safety coefficient concern
\( t = 3 \) for high safety coefficient concern (the test plan uses this concern)

\( RH0 = 0.1 \) for excellent super structure concern
\( RH0 = 0.2 \) for good super structure concern (the test plan uses this concern)
\( RH0 = 0.3 \) for poor super structure concern

\( PHI = 1 \) for speed lower than 60km/h
\( PHI = 1 + \left( \frac{V - 600}{140} \right) \) for speed larger than 60km/h (the test plan uses 130km/h for design purpose)
FR: The deviation factor of the base line, which is exerted by the central force of the wheel and suspension load

=1.1~1.25 for general train
=1.05 for general light weight train

FA: Bearing coefficient of individual span

= (SV/SS) 3/4

SV: Expect span
SS: Standard span distance 650mm
FP: Figure coefficient of rail

= (is/iv) 1/4

is: for standard inertia torque rail is 2000cm$^4$

iv: for inertia torque 50N rail is 1960cm$^4$

4.1.2.4 According to the in-situ displacement measurements and stress analysis report of the TRA Nankang River Bridge slab trackbed system, it was noted that the effective dynamic loading value is 6t, and the safety factor 1.1 is assumed for setting out the vertical dynamic loading test. The in-situ measurement of lateral and vertical ratio made by TRA is 0.38 (actual adoption of 0.4).

The Taipei Rapid Transit System also conducted its own dynamic-vertical and repeated lateral loading tests, in which the ratio of vertical pull and outside loading of rail derived from the test is 1.1, counting the rail outside loading due to pulling. As to the lateral loading test, a conservative value of 0.6 was adopted for the vertical/lateral fatigue test of rail fastener based on the British Rail Research calculation.

4.2 The research of fastener of non-ballasted track

The following text summarizes the studies on corrosion and vibration

4.2.1 In view of the rich sulfur content and air pollution in the Taipei basin, the air may have a tremendous impact upon metal products (fastener, clip, bolt, rail, etc.), which may shorten the service life of the track. The Taipei Rapid Transit System (TRTS) has therefore entailed a corrosion study of the trackwork in order to evaluate the safety-related aspects in light of the metal properties, rail fasteners, and structure safety, and establish the anti-corrosion criteria. The criteria was based on the Fossil Power Plant of Taiwan Formosa Company at the Mai-Liao sea frontal area and regulated the quality characteristics of metal products under severe climate conditions for 1000 hours in line with ASTM B117. The grade should be 8 or more to be in line with ASTM D1654 and ASTM D610 standards.

4.2.2 The vibration level of non-ballasted track due to train movement on railway is rather higher than that for ballast track; therefore, the rail fastener shall play as the main mechanism for the vibration-reduction factor. The Taipei Rapid Transit System designated the Chinese Society of Sound and Vibration to conduct a
level measurement and test research plan so as to enhance the understanding of vibration reduction of elastic rail fastener of rail. With a view of maintaining the monitoring system to be in compliance with the actual stiffness and mass conditions during the process of testing and measuring the insertion loss, it was decided to place six types of sandwich base plate on the surface of elevated rail plinth. The test conducted speed deviation for horizontal/vertical direction or insertion loss. It was found that the 1st modal frequency lies within the limit of 40~100Hz, and it was also found that the scale of the vibration-detention level appears to be larger in case the stiffness of base plate is reduced.

5 The History and Development and Production Experience of Resilient Rail Fasteners in Taiwan

Both the TRTS and TRA have adopted the use of direct fixation track in Taiwan since 1990. Details of their utilization are noted as follows:

5.1 The experience of the Taipei Rapid Transit System (TRTS)

The consulting firm, American Transit Consultants (ATC), designed the rapid transit system for Taipei. Direct fixation fasteners (DFF) were used on both elevated and tunnel sections, including the Lord DFF for the Tanshui and Chungho lines, and ATS DFF for the Hsintien and Nankang-Panchiao lines.

A. Lord DFF: (a) Sandwich base-plate (top and bottom plate were metal, middle layer was elastic pad, fully bonded with vulcanization), (b) Spring coefficient: 15.76 KN/mm (±10%) for tunnel section, 20.38 KN/mm (±10%) for elevated section, (c) Anchor bolt only through bottom plate, (d) Top plate cast-in down and bottom plate cast-in up act like an inner snubber.

B. ATS: (a) Sandwich Base-plate (top and bottom plate was metal, middle layer was elastic pad, fully bonded with vulcanization), (b) Spring coefficient: 15.76KN/mm (±10%) for underground, (c) Anchor bolt only through bottom plate, (d) Top plate and bottom plate is wave shape overlapping.

The ATS rail fastener was manufactured jointly by local Taiwan companies. The TRTS has been conducting studies on several types of DFF (including Lord, ATS, and Getzner) for natural frequency resonance and insert loss for rail corrugation and environmental considerations.

5.2 Taiwan Railway Administration (TRA)

Since 1993, the TRA has already developed two types of non-ballasted track as follows:

A. Nankang River Bridge: (a) Use PANDROL clip, (b) Use adjustable type rail pad.

B. Miaoli Tunnel: (a) Use PANDROL clip, (b) Use rail fastener base plate of CLOUTH's product, which is manufactured in Taiwan through an international corporation contract, (c) Elastic coefficient: 25±15%
KN/mm, (d) The anchor bolts screw into the outer ring of metal plate.

6  Non-ballasted trackbed

There are so many kinds of non-ballasted trackbed designs in the world, and the following text will illustrate the analysis and experience accumulated in Taiwan.

6.1 Taiwan Railway Administration (TRA)

6.1.1 Nankang River Bridge (1993)
The rail clip PR113A of the Pandrol system was adopted with 300–400kg of clip pressure, nylon insulation pad and 10mm thick rail rubber mat. The variable mat (resin material) is injected into the space between the rail pad and slab. Also, Japanese A-155 type slab track is adopted in this system.

6.1.2 Miao-Nan tunnel (1998)
The rail clip PANDROL was adopted with elastic base plate concrete slab, which is similar to the special trackwork area of the Taipei Rapid Transit System.

6.2 The East Railway Re-construction Bureau

The Bureau adopted PANDROL clip and Japanese type concrete embedded track plinth, and the spring constant of elastic material of 20–30 tf/cm.

6.3 Rapid Transit System

The Taipei Rapid Transit System adopted two types of trackbed i.e. track plinth and track slab with 12–15m in length, T/R-400 in height and elastic rail fastener. The long welded rail was adopted for the whole system except the rail insulation joint area, and the longitudinal confined force of elastic clip was designed to control the interaction between the rail and bridge to ensure effective control of the trackwork.

7  The design of elastic rail fastener and test approach and specifications

The design of the elastic rail fastener is basically in line with the various features of the system and functional requirements, and the related testing loads could be regulated through actual measuring results at the site. In principle, the test plan of the non-ballasted elastic track of the Taipei Rapid Transit System (TRTS) is directed in accordance with the USA non-ballasted elastic track clip experience.

7.1 Test plan of Direct Fixation Fastener of TRTS

7.1.1 Stage 1: CT501 trackwork contract
The design lot Contract CT501 was the first contract of the TRTS, and the system parameter and functional requirements are stipulated in the contract so
that the contractor has to set up a test plan based on the system characteristics.

7.1.2 Stage 2: CH521, CN531 and CP541 contracts

Based on the previous experience of the guideline, the DFF test plan was proposed as follows: (a) The basic test plan framework is based on the American DFF test plan, (b) The environmental factor was defined for the corrosion test, (c) The "fail safe" requirements were added into the test plan.

7.1.3 Stage 3: CD511 Contract

The revised DFF test plan is included in the specifications (CD511 Contract) to reflect the real situation, and the modifications of the DFF test plan were based on discussion carried out among the TRTS, Chung Shan Institute of Science Technology, Industrial Technology Research Institute and DFF’s supplier. The test process was designed to accurately simulate the real service situation of DFF in one sequential procedure. The testing sequences are as follows:

7.1.3.1 Sequence of the qualification test (5)

This qualification test was designed to verify whether or not the DFF meets the origin system characteristics and contract requirements. It can also be used in cooperation with other interface system requirements, such as wheel and track interaction, smoothness of track plinth surface...etc.

The DFF qualification tests were selected and performed on a group of four fasteners in accordance with the following test procedure with the loading as shown for each fastener. Mechanical tests were performed on a group of four fasteners (each 25.4mm space), in which all of the fasteners were shimmed 20mm in accordance with configuration requirements and the outside two fasteners were shimmed 2mm additionally to simulate the elevation deviation of adjacent fasteners.


7.1.3.2 The Sequence of Production Quality Test [5]

The production quality testing sequence was designed to ensure that the routine products could keep a good quality to meet the contract’s requirements. The test items were selected in the qualification test, and the method and acceptance criteria were the same as that of the qualification test.

The Production Quality Test included: (a) Voltage withstand test, (b) Electrical resistance and impedance test, (c) Dynamic to static stiffness ratio test, (d) Vertical load test, (e) Vertical uplift test, (f) Lateral load test, (g) Lateral restraint test, (h) Longitudinal restraint test, (i) Vertical and lateral repeated load test.
7.1.4 Stage 4: For the future contracts
Since there were rail corrugation, noise and vibration problems associated with the operation of the Tamshui Line Contract CT501 from February 28, 1997, until the present, all possible causes and solutions were studied and analyzed. Four potential requirements of the DFF track were proposed as follows: (a) To define the DFF’s track natural frequency, (b) To define the DFF’s damping ratio, (c) To avoid the same natural frequency with car body, (d) To evaluate the DFF’s insert loss. We believe these four requirements will be the present force for the set up of a universal specification in the near future.

8 The design and evaluation of the non-ballasted trackbed

In view of achieving the best design and construction of non-ballasted trackbed, the following must be considered and taken into account as the basic parameter in the analysis and evaluation process:

8.1 Design Loading: For the entire railway system design, it is necessary to draw attention to the system’s own specific train mode and axis weight and conduct the preliminary structure analysis through the system in reference with the other related non-ballasted trackbed system.
8.2 Design Speed: The train speed is also taken into full account and evaluated for the preliminary evaluation of the rail stability through the system in reference with the other related non-ballasted trackbed system.
8.3 Track Confine Force: The trackbed shall provide a smooth and continuous bearing surface for train driving. Therefore, it is vital to evaluate the overall integral combination of parts and effective control to ensure the safety and avoid any possibility of danger due to dynamic loading behaviors or temperature change to induce the improper expansion or shrinkage of rail.
8.4 Displacement of the rail: The consideration shall be given on account of the safe limit of deformation or displacement due to the running of train on the rail of trackbed, and ensure the performance of train safety.
8.5 Spring coefficient: The spring coefficient of elastic material for a non-ballasted trackbed system shall be evaluated in order to ensure the avoidance of the extensive limit of high or low values. This is to maintain the safe requirements of train operation (usually the spring coefficient of a mass rapid transit system in North America or South-East Asia is around 14~21kn/mm, and a higher value for a high speed railway system).
8.6 Noise Absorption and Vibration Reduction: To preserve a high quality of living for the people who live alongside the railway alignment, it is necessary to evaluate and assess the vibration-reduction. This is to enhance the understanding of minimizing the impacts on the surrounding environment and propose the mitigation approach to promise an improvement to the noise and vibration level in specific areas.
8.7 Resonance between the Train and Structure: The resonance between the train, rail, and trackbed structure might result in resonant oscillation, which will induce the secondary noise and vibration and deteriorate the level of environmental pollution.
8.8 Electricity Insulation: The power supply system needs to be carefully designed to minimize the adverse impacts and property loss due to the occurrence of electric corrosion along the railway.

8.9 Degree Of Automation: The degree of automation capability might play an important role on the non-ballasted trackwork system construction and affect the shortening of the construction schedule and accuracy of work at the site.

8.10 Ease of Construction: The design should take account of the scale of construction difficulties at the site to avoid any building impediment in advance.

8.11 Time and Convenience of Maintenance Work: The evaluation of non-ballasted track work should pay attention to the ease and convenience of maintenance upon the completion or operation in the future.

8.12 Anti-Corrosion: The design of a non-ballasted track system should draw particular attention to the feature of rail anti-corrosion performance to ensure that the train could maintain safe operation in adverse and severe corrosion atmosphere conditions.

8.13 Test Plan: The test plan of the non-ballasted track system should ensure that the design function shall be properly managed or satisfied, which basically includes the tests of material strength, endurance, anti-corrosion, spring coefficient, electricity insulation, track stability, vibration reduction, displacement restriction, resonance, and scale of displacements, etc.

8.14 Economic Evaluation: Aside from safety concerns, the economic evaluation plays a rather important parameter on the construction of a non-ballasted track system. This includes the accurate estimation of individual stages (for instance, the cost of design, material, construction, maintenance and operation) and a re-evaluation of the effectiveness and overall budget allocation in a way to make the appropriate choice and decision.

After an overall evaluation, it is actually strongly recommended to select those cases which have a higher initial construction cost of trackwork, but have less maintenance expense in subsequent operation and revenue periods (as opposed to other cases with some initially low construction cost, but a higher operation cost in the revenue period).

9 The elastic trackbed of railway

The noise and vibration pollution associated with the modern railway system is still a knotty problem for the residents along the line, and the resolution approaches are always a topic of discussion and study, especially on the subjects of elastic baseplate, elastic trackbed, and rail enveloped by elastic material, etc.

There are many types of elastic trackbeds, such as Stedef tie, tie with rubber boot, floating slab (mechanic type and elastomer type), etc. However, at present, it is noted that the floating slab is the effective approach for measures to solve the noise and vibration problems in environmentally sensitive areas. The latest information indicates that the noise and vibration level can be reduced by an amount in the range of 15~40 db, with a more broad limit of reduction resonance spectrum as well.
9.1 The elastomer type of floating slab

The elastomer type of floating slab is composed of concrete slab integrated with elastic material (nature or synthetic rubber) to act as mechanical floating slab and enhance the vibration reduction spectrum through the mechanism of concrete slab weight and spring coefficient supplied by elastic rubber. The elastic rubber of elastic support pad could absorb the vibration by compression deformation of elastomer and reduce the level of vibration resulting by train movement and maintain the avoiding of resonance frequency in a specific limit. There are two types of elastic support pad as follows:

9.1.1 The elastic pad type: The elastic material of this type is designed by the railway consultant on the basis of the size of the concrete slab and arranged under the slab to absorb the energy of the vibration quantity by three directional elastic expansions or shrinkage in the course of train movement.

9.1.2 The rubber boot mat type: The elastic material of this type is developed by railway system analysis to design the suitable thickness of rubber boot and forecast the elongations of compression displacement so as to ensure the under or perimeter surface of concrete slab to be completely enclosed by elastomer acted as a boot to cover the concrete slab, excepting the top surface.

9.2 The mechanical type of floating slab:

The mechanical type of floating slab is composed of concrete slab integrated with helical spring to act as various spring coefficient combination (elastic stiffness value) and enhance the vibration reduction spectrum through the mechanism of concrete slab weight and spring coefficient supplied by helical spring.

The mechanical type of floating slab could absorb the vibration by compression deformation of helical spring and reduce the level of vibration resulting by train movement and maintain the avoiding of resonance frequency in a specific limit. Not withstanding the above-mentioned chapters, it must be emphasized that the vibration-reduction design of a railway track system shall take into full account the occurrence of resonance or anti-resonance effects due to the combined action of natural and structure vibration frequency. Even by the nature of significant differences of mass between the train body and rail fastener, the proper design still shall pay attention to this problem. If the floating slab is selected for trackbed, the design should be carefully examined to ensure the avoidance of coupling resonance or anti-resonance effects due to natural frequency in association with the floating slab, fastener, train and structure combinations.

At present, CECI is conducting research on floating slab, and expects to document and structure the domestic and international data base, design flow-chart, principle, and research very shortly, as well as establish the design capacity of floating slab in the near future.

10 Conclusions and Suggestion

With the characteristics of ease of maintenance and a stable structure, the direct fixation track system will be widely used around the world. Even though there are different types of direction fixation track for different railway systems (such as
high speed railway system, mass rapid transit system, traditional railway system, light railway system), all of these systems still have the same design principle. The design requirements procedure should include the following items:

- To analyze the interaction between the track and elevated structure
- To analyze the distribution of wheel load
- To analyze the environmental impact
- To carry out a fail safe design
- To analyze the DFF inserts loss (for reducing the noise and vibration in the track)
- To avoid the same natural frequency between the track structure and car body
- To analyze the suitable stiffness and damping ratio,
- To set up a proper test plan (both pre-qualification test and production test) that could ensure the quality of the DFF

It is hoped that the experiences gained from the direct fixation rail fastener of the Taipe Rapid Transit System, especially in the test plan, could be shared with other railway systems. At the same time, the experiences of the other railway systems could also be shared with other parties. Through the exchange of our experiences and technology, we believe that the railway track system will be improved in the near future.

References

[5] TRTS Track specification - department of rapid transit system t.m.g.