The safety measures against deformation of the track

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Abstract

This paper makes an extensive evaluation and investigation of the safety strategy against the deformation of the track induced by the deformation of the civil structure, during the design, construction and operation stages. An overall analysis is based on the local practical field experiences, and the safety and maintenance regulations of other countries. The suggestions and conclusions are proposed with regards the case study of the Taipei MRT system. We hope this paper will be helpful for the future execution of the railway transportation system in the world.

For the inland transportation system around the world, due to the population concentration in metropolitan areas, insufficient supply of the road capacity, the environmental protection, escalating living standards and the energy crisis, the railway transportation seems to be the best choice to cope with the demand to reduce pollution and effectively use the energy resources. Due to the long narrow topography and steep mountain ridge, there will be many railway transportation projects proposed in the next 20 years in the Taiwan area. The study and construction of the railway transportation systems will be the trend for the future development in the academic, government and industry fields in Taiwan.

Key words: Safety remedy measures, deformation.

1 Preface

The Mass Rapid Transit System (MRTS) mostly goes through the main traffic routes in the metropolitan area. The first domestic MRT—Taipei MRT—is in Taipei city. Most of the routes go through urban roads while part of them go under citizens’ houses. As MRT was under construction, nearby buildings had
been constantly built. Thus, it made the tunnel float up, collapse, and slide. Even soil stress and underground water level around the tunnel were impacted, and the tunnel was squeezed and became deformed. This kind of accident happens very often and causes the deformation of MRT structure and track. The whole structure is destroyed and the track becomes distorted, which, as a result, influences the operation.

The track is to support steel wheels, so the running surface of track needs to be very smooth and its alignment good. In so doing, the service quality can be guaranteed.

Generally speaking, there are two railway track systems—Ballasted track and Non-ballast track. The Ballasted track can be adjusted on the spot to deal with the track deformation while the Non-Ballasted track is more complicated. Non-ballasted track needs to be dealt with via systematic methods. Taipei MRT track will be used as an example; its analysis of the safety coefficient should be based on the maximum strain and stress of DFF. In practice, the adjustment of the steel rail baseplate should be used to solve the deformation problem in order to prevent elastic materials in DFF from dropping and breaking, so as to cause derailment. Based on the Taipei MRT characteristics, this study intends construct a set of adequate track adjustment numbers to avoid invalidity of DFF. Meanwhile, non-ballast track is fixed on concrete structures. For track elements, the steel rail is the one to directly support the steel wheel. The stable degree of the steel wheel mainly becomes the one to operate the stability, comfort and safety while driving. The steel rail is directly fixed onto a concrete structure by rail fasteners that determine service grades.

The Taipei MRT characteristics include ballast and non-ballast track. Under the track, there are three types of structures—At grade, elevated support and tunnel structure. The track deformation is due to structure movement. Based on safety, track must be adjusted within a comfortable and safe degree for the purpose of transportation.

Recently, international transportation has promoted the Intelligent Advanced Transportation Management System (ATMS) which is considered to be the core of the intelligent transportation system. ATMS has a range of advanced techniques such as traffic detectors, modem telecommunication, information management and traffic control. It can transmit the traffic situation to a computerized traffic center by means of a high-speed telecommunication network. The traffic control center combines information from other systems and carefully analyzes this information so as to build efficient traffic control strategies and execute traffic management. Also, it sends relevant information to pedestrians & drivers and the relevant traffic management department in the hope of promoting and enhancing transportation efficiency and safety.

2 An analysis on track safety and comfort and stability

Safety and comfort are based on the following elements:

1. While trains are driving on the track, its interface is the steel wheel and the rail. So the bearing surface of the steel rail controls the safety
and passengers’ comfort. A railway transportation system involves a large number of passengers. Naturally, it demands high quality. General railway systems are mostly based on the original system design level with regard to comfort. The smoothness of the running surface of the steel rail is also based on comfort. All kinds of control values in this study are based on maintenance values of MRT companies. The following sections examine MRT track system safety and maintenance in San Francisco.

(2) The practical supply of track structures and components is another element to control train safety and passengers’ comfort.

3 Relevant track safety rules

Relevant track safety rules, abroad and domestic, are stated as follows.

3.1 Analysis on MRT safety and maintenance regulations in San Francisco

The safety of non-ballasted track components is based on the MRT track safety standard in San Francisco. The invalid rail fastener about non-ballast rail on p174.2.3 are analyzed as follows.

(1) Damage of hooks
(2) Unable to fix baseplate on account of the loss and damage of two anchor bolts.
(3) Unable to locate in baseplate position because of release of pre-cast anchor bolts.
(4) Erosion and damage of baseplate make steel rail fasteners unable to support in laterally and vertically
(5) Damage of concrete surface under baseplate is unable to support efficiently.

3.2 Analysis on Taipei MRT non-ballast steel rail fasteners

(1) Damage of hooks
(2) Unable to fix baseplate on account of the loss and damage of two anchor bolts.
(3) Unable to locate in baseplate position because of release of pre-cast anchor bolts.
(4) Erosion and damage of baseplate make steel rail buckles unable to support laterally and vertically
(5) Damage of concrete surface under baseplate is unable to support efficiently.
(6) This study analyzes and builds track safety coefficients according to tunnel deformation leading to track slide and inefficient track components. Based on maximum DFF variation, it can keep fasteners away from being deformed and damaged elastic materials. A matter of safety may not happen.
Generally speaking, when tracks are deformed during operation, there is a need to keep track components safe and stable for driving safety and passengers’ comfort. At the same time, different methods will be adopted to solve track deformation and track smoothness in order to achieve the purpose of driving safety.

The following sections will further discuss the amount of track deformation and procedures.

### 3.3 Railway safety protection rules in other countries

#### 3.3.1 Railway protection technical rules in Singapore

1. Non-ballast track rules between underground and day-lighting.
   a. Differential movements cannot exceed 3mm every 6m on any tracks or its plinth. On any other MRT structure or tracks the total movement cannot exceed 15mm.

2. In elevated structure, rules of ballast tracks are stated as follows:
   b. Distance between two rails cannot exceed 1:1000 (track distortion)
   c. Vertical height on the top of tracks cannot exceed 1:1000 or 5mm every 5m.
   d. Lateral movement cannot exceed 1:1000 or 6mm every 6m.

3. If any rule mentioned above happens, the construction should be terminated until MRT operation units improve it. Applicators deserve to afford all of the cost. Whatever happens, the total lateral movement cannot exceed 20mm.

#### 3.3.2 Relevant rules in Hong Kong MRTS

1. B.1.(b) in PNAP77 appendix A (Annex 2&3) mentioned: Technical Notes For Guidance in Assessing the Effects of Civil Engineering Construction/Building Development on Mass Transit Railway Structures and Operations. Relevant rules are stated as follows: Differential movement resulting from the works shall not produce final distortion in any MTR structure including the plinth or track in excess of 1 in 1000 in any plane or a total movement in any MTR structure including the plinth or track exceeding 20mm in any plane.

#### 3.3.3 Temporal guidelines for construction in Tokyo high speed tram, Japan define its track limitation:

1. Track height 7mm/10m
2. Direction 7mm/10m
3. Standard 7mm/gauge

In special trackwork areas it even strictly defines 2/3 times than other spots for the sake of high safety.
4 Analysis on the influence of track deformation

Analysis on the influence of track deformation will be carried out on the basis of track components safety and stability, driving safety, and passengers' comfort.

4.1 Influence

(1) Tracks are the main components to support trains. Taipei MRT uses non-ballast tracks directly located on structure frames (elevated bridges or tunnels). When structures are affected by outer elements and cause movement and deformation, tracks will also be influenced and move. So it will affect the shape of tracks and distance between tracks and structures.

(2) Track movement leads to distorted track shapes. The way to deal with such situations is different in accordance with damaged degrees. (Usually it divides into three grades: observation, normal management procedures, and emergency management procedures.)

(3) Track movement causes the deviation of clearance between tracks and structures. According to practical situation, proper management procedures will be done on the basis of minimum clearance demands.

4.2 Analysis

(1) According to systematic track characteristics (ballasted tracks and non-ballasted tracks) and structural types (elevated, tunnel and ground), relevant recommended numbers or treatment methods will be done.

(2) Taipei track characteristics can be divided into ballasted track (at grade) and non-ballasted (elevated section and tunnel section). According to track contracts: B.3.a &B4, section 1.05, Chapter 02468, non-ballasted track rail fasteners need to be adjusted vertically and laterally. Further analysis is stated as follows: the steel rail in non-ballast is directly fixed in a concrete base. Direct fixation fasteners still can be adjusted 15mm vertically after fixation. (Shims insert under baseplate and keep original track design the same) and 15mm laterally (to gauge side or outer side of the rail) Considering maintenance demands as 5mm, Fastener system still can be adjusted 10mm vertically and 10mm sideways.

(3) To increase the sufficient laterally adjustment between two sets of rail fasteners can be fixed another rail fastener on a concrete plinth. Drill two holes for anchor bolts opposite direction of structure shifting from original anchor bolts about 20mm. Maybe it can increase track lateral capacity up to 25mm. 10mm (the designed figures) and 15mm (Redrill a hole in 20mm opposite from original position) are 25mm. Although baseplate can be adjusted to 30mm, but we keep so numbers for structure restore and 5mm for the maintenance of both sides, it still has 15mm to adjust.
Non-ballasted rail fastener system in Taipei MRT uses a sandwich baseplate that can reduce vibration well (Its structure is metal and only uses glue to stick the elastic materials without any other mechanical connection). This study focuses on baseplate characteristics and the elastic materials’ ability to support variation (strain/stress no more than 50%, $28mm \times 0.5 = 14mm$). To collocate with forever track deformation on account of tunnel movement and temporal track deformation, the two variation figures and situations will be taken into consideration together with elastic function (no more than 50%, $14mm \times 0.5 = 7mm$). Forever track deformation should be controlled between 3mm and 4mm. At present, Taipei MRT non-ballasted rail fasteners adjustment is 3mm/one time.

5 Track suggestions in treatment procedures

Owing to nearby buildings development, civil structure (elevated section, tunnel, and aboveground) makes the whole tunnel float up, collapse, and move laterally. Tunnels produce the change of soil and underground water level and therefore lead to accidents. Railway structures and track deformation move, further destroy structure & the shape of track line, and influence to the operation.

For safety, the tracks need to be adjusted back to comfort and safety. Ways to deal with Taipei MRTS adjustment are stated as follows:

5.1 Track adjustment treatment

Characteristics of each railway system and citizens’ right are the top priority in dealing with track construction adjustment. (e.g. Taipei MRT) Basically there are two ways according to ballast types.

1. If clearance is sufficient, track alignment will not be changed that rail fasteners was adjusted. They will stay just like original system grades to avoid prolonging crisis management period.
2. Non-ballast: If track doesn’t change too much, partial adjustment is adopted. On the contrary, if the change is significant, it had better relocated rail fasteners fixations to adjust tracks.
3. Ballast: If track doesn’t change too much, it had better use traditional ballasted track adjustment. It uses ballast-filling method to adjust tracks.
4. If tracks move a lot by external pressure, it should be largely improved according to safety and comfort standard rules.

5.2 Suggestions on non-ballast adjustment treatment

After analyzing Taipei MRT non-ballasted tracks, here are some suggestions.

1. In order to keep non-ballast from collapsing or moving when nearby buildings are excavated, contractors should negotiate with railway
(2) After contractors make sure the figures are correct, rail fasteners can then be adjusted at once.

[A] Investigate track movement areas beforehand and record vertical and horizontal figures each datum acquires.

[B] Prepare needed shims.

[C] Workers along with materials are allowed to enter the construction position under the agreement of railway management units.

[D] Mark the adjustment amount on track plinth beside baseplate first.

[E] Release screws in movement areas and 5-10 rail fasteners close to movement areas.

[F] Set up a jack to jack up steel rail.

[G] Vertical adjustment: Insert shims under rail baseplate according to shims amount and types.

[H] Horizontal adjustment: Adjust figures to move baseplate right or left according to present marks (3mm/one time) so that the original track alignment can be maintained and reached to the demands of safety and comfort.

[I] Make sure the adjustment is finished and re-lower steel rail on baseplate.

[J] Screw up anchor bolts in baseplate again.

[K] Re-install rail fasteners.

[L] Workers and materials leave the spot after complete the adjustment.

(3) Methods of conductor rail adjustment:

[A] Conductor rail and track are relative position.

[B] Two ways of adjustment for conductor rail

[C] Release bolts to adjust conductor rail brackets (the use of an Adjustable conductor rail bracket is suggested).

[D] Re-drill a hole to locate pre-cast anchor bolts.

[E] Procedures are similar to non-ballasted track according to practical situation.

5.3 Ballasted track adjustment

To keep ballasted track from collapsing or moving during excavation of nearby buildings, those responsible for the new developed buildings should negotiate with railway units to set up equipment at a certain area and key locations to detect the original figures for future comparison.

When tracks deform more than standard figures, it is necessary for MRT operation units to adjust them according to the maintenance manual.
6 Conclusion and suggestion

Unlike other public construction, the railway construction system develops as a line distribution rather than a single area. Its developmental type ‘line distribution’ is like road construction.

With further analysis, the road transportation is quite different from railway transportation in many areas. Vehicles on roads are mainly single unit while trains consist of multiple units. Meanwhile, wheels of vehicles are plastic, but wheels of trains are mostly steel. Even though their developmental types are quite alike, the demand for support is different. The requirement of bearing surface in the smooth and accuracy is quite different. The control unit for railway tracks is mm, so any deformation on civil construction will immediately affect driving safety and passengers’ comfort, and even destroy track construction.

From the above discussion, railway track construction is to provide driving safety. As soon as the goal is achieved, it needs to coordinate with a variety of treatment measures.

There are two suggestions for the management of structure deformation. Another is a suggestion for general railways.

(1) At the beginning of building railways, complete background data should be collected. This information includes construction range and geology, drainage, nearby buildings, metropolitan planning, environment, etc. Also, the data bank should be established about construction and operation.

(2) Based on track records, establish the total track data bank for safety and maintenance.

(3) According to the type of track to solve structure deformation

Considering characteristics of Taipei MRTS track, some reasonable suggestions are stated as follows according to non-ballasted track safety and maintenance. Other railway systems can take into consideration if similar situations occur.

(1) If tracks in any plain deform and lead to track distortion up to 3mm/5m (Baseplate lateral adjustment units is 3mm), it needs to take standard action. That is, release bolts to make the baseplate move in order to adjust tracks. If track movement reaches 10mm, it is necessary to evaluate the whole situation.

(2) If tracks in any plain lead to distortion up to 6mm/5m, it needs to take emergency action. And the total movement cannot exceed 20mm (It is scheduled to keep 5mm as emergent maintenance, and the emergent adjustment figures would be adjusted according to the demand of operation department).

(3) Detection on track deformation will base on tunnel segment and track relative deformation.

(4) To increase track adjustment ability, suggestions about vertical adjustment and lateral adjustment will be made in the future design to rail fastener system.
This study mainly focuses on providing driving safety in civil structure deformation, and strategies to solve the problem. In this study we hope to find out other solutions by other railway systems.

Reference