Application Research of GRP3000 Absolute Coordinates Track Survey System on Trackworks Construction

Mr. SHEN Tsung-I, Mr. CHANG Che-Hao and Mr. HUANG Pei-Yuh, Chinese Taipei

Key word: Absolute coordinate track survey system, Gauge, Cant, Non-ballast track, Total station theodolite

SUMMARY

Recently for the construction and survey of trackworks construction, by using the survey instruments, like theodolite and/or hand tools are still the traditional way. For the setting of track center and rail elevation are still mainly by the theodolite and the level, and then with different instruments or tools for those different measuring item's final adjustment and/or measurement, such as the rail gauge meter for track gauge and cant, alignment gauge block for the horizontal and vertical veracity measurement. Those traditional survey or measurement (gauge, cant/cross level, horizontal/vertical alignment, and twist) are refer to the measuring point vs. it's adjacent point and their reference relationship in between, but can not assure the deviation between the measuring point and it's absolute coordinates. Recently the accuracy of trackworks pavement works had been more stringent than ever before, the accuracy of traditional manually measuring method are now unable to reach the accuracy requirement, and then the high accuracy absolute coordinates survey system is now the tendency for trackworks construction.

Using the Leica-GRP3000 absolute coordinates track survey system is in corporate with the high accuracy total station theodolite with additional automatic researching, wireless transportation, computer, and track alignment computation/comparison program, this not only can provide the deviation between the design alignment and the actual paving condition on site, but afford the construction team the on site real time adjustment work. Laser measuring system can also be added to measure all relative adjacent buildings, platform, and the other on site mechanical/electrical instruments, and provide their three-dimensional absolute coordinates (N.E.H) to have the real time inspection and adjustment work, and also for those reference requirement such as the rolling stock clearance or envelope diagram, to assure the operational safety.
This application/research are base on the trackworks construction of Railway Reconstruction Bureau(as RRB), MOTC R.O.C. Nan-kang Extension Project by using this system for their trackworks construction project, not only at construction stage but for the as built approval inspection. It had been certified, after research and compare, that this system can perform high accuracy trackworks construction work, especially for the non-ballast track system's repetition, complicate and high accuracy inspection work and as a competent instrument with satisfaction.

It is the first time for RRB to use such survey system for trackwork construction instead of the traditional way. This operation mould and its' effect had been approved not only at manpower-saving, more efficient for working, but the accuracy result conform modern precise requirement. To provide this surveying experience for the other project and also to

impart this more effective and more accuracy operation mould, is our main purpose for this research.

Application Research of GRP3000 Absolute Coordinates Track Survey System on Trackworks Construction

Mr. SHEN Tsung-I, Mr. CHANG Che-Hao and Mr. HUANG Pei-Yuh, Chinese Taipei

1. INTRODUCTION

Currently, trackworks construction positioning in Taiwan is done mainly via conventional survey instruments. Setting of track center and rail elevation is still accomplished through the theodolite and the level. Different manual instruments/tools are employed then for final adjustment, positioning measurement and verification of different items, such as gauge, cant/cross level, horizontal/vertical alignment, and twist. For instance, the rail gauge meter is used for track gauge and cant, alignment gauge block for the horizontal and vertical versine measurement. These traditional survey/measurement approaches measure the relative position of the rail in accordance with its surrounding reference control points, but are unable to verify the deviation between the measuring point and its absolute coordination. No in-depth exploration has been conducted. The only thing done is superficial work that makes the appearance of the track smooth and presentable. In recent years, requirement on trackworks pavement precision has become more stringent than ever, and traditional low-precision measurement methods that are manually performed have been unable to meet the requirement. Application of the high-precision absolute coordination survey system will be required for future trackworks construction.

This application exploration is based on the survey tasks pertinent to trackworks construction of Railway Reconstruction Bureau (RRB) Nankang Extension Project as the subject of case study. The system is utilized throughout the entire trackworks construction and inspection process. Even though this track survey system is in use for the first time, it is still employed as the primary operational model in association with conventional track survey methods as supplementary in order to meet the high-precision requirement of trackworks construction today. Thereby we familiarize ourselves with the new track survey system and verify whether there is deficiency in conventional track survey methods and design/alignment outcomes. The purpose is to record this test experience for future reference and to propose a standard operational model that effectively coordinates trackworks construction and survey procedures, that expedites trackworks construction survey and enhances its accuracy.

The verification confirms this system expedites high-accuracy trackworks construction. It is an effective track pavement tool, especially for the "non-ballast track system," which involves repetitive, complicate procedures and various delicate adjustments and inspections. The Leica-GRP3000 absolute coordination track survey system consists of high accuracy total station theodolite with automatic searching, wireless transmission, industrial computer, and track alignment computation/comparison program. It is able to show current track conditions and alignment design deviation real time on the construction site to help track pavement workers make necessary adjustments. The attached laser measurement system is for survey of buildings, platforms and electrical/mechanical facilities surrounding the rails, furnishing their three-dimensional absolute coordination (N.E.H) for real-time determination of the clearance between the tracks and their surrounding objects, as well as comparison with demarcations of adjacent buildings, in order to determine the safety clearance of train operations.

2. SURVEY IN TRACKWORKS CONSTRUCTION

2.1 Scope of Trackworks (Railway) Construction

Termed track construction or railroad management, the so-called simple trackworks construction encompasses transportation, construction, mechanical matters and electrical matters. It is a fairly complicated and expansive construction undertaking. Yet the attention of this study has been fastened on positioning technologies pertinent to trackworks construction and survey.

Railway design must takes into careful consideration requirements on the route, alignment, track structure, structure materials, turnout, track maintenance/management, track repair standard and railroad maintenance operations. The methods and procedures are different from conventional railways to high speed rails, to metro systems in accordance with the alignment guidelines and construction specification.

The steps and procedures of the track laying and inspection of the survey are always the same. Different trackworks may necessitate different approaches. For instance, between the traditional ballast tracks and the more popular non-ballast tracks, the complexities of the operational procedures are different. Inspections involved in the final track-pavement positioning are also drastically different. The former is mainly concerned about smoothness of the route while the latter uses alignment design data for comparison and for fine adjustment of the route. This is the main issue that this study delves into.

2.2 Relationship between Trackworks and Survey Procedures

Following understanding of the scope of trackworks construction, we consider the fact that train operation involves the track system that comprises the rail, clips and the bearing system to connect towns and cities. Its routes, slopes and operation speed are to be completed in different planning and design stages according to the requirements. After the design is finished, the horizontal position and vertical slope, which are termed "horizontal alignment" and "vertical profile (section) alignment" respectively, will be determined according to the route, slope and operation speed.

However, the most important part for the construction survey is the protection /maintenance of the control pile position because the control pile position is the crucial factor that determines position and elevation accuracy of special construction projects. For the preparation of trackworks constructions, the center and elevation of the track designed need to be set on the site. The established points of the setting will be marked as the operational basis of the track construction team. In conjunction with the operational model and procedures of trackworks construction, 2 settings are generally required for the same designated linear setting points. During the second setting, demarcation is required to show the center of the track or the elevation of the track surface, which will help the trackworks construction team with fine adjustment of track positioning.

Track alignment requires survey of the setting points, including control points for curve (TS, SC, CS, ST, BC, EC, PCC) and turnouts (BT, ETM, ETS), as well as track center control points (every 10m on a curve and every 20m on a straight line).

Upon completion of track center setting, clearance of all adjacent structures of the track center needs to be checked. The main purpose is to measure the distance between the structures and the track center if they are situated within 2 meters of the track center. This way we can identify the clearance between the tracks and their surrounding objects and compare them against demarcations of adjacent buildings real time in order to determine the safety of future train operations.

When horizontal adjustment of the track center is conducted according to track center setting outcomes, based on direct leveling elevation the track surface elevation is positioned to the designed level through the vertical adjustment board. For the curved section, another steel track is required for cant construction. Repetitions are required until the track center position and the track surface elevation complies with the design criterion.

When comprehensive inspection determines that the gauge, horizontal/vertical alignment, direction and twist are in compliance with the standards, the hardware structure of the track has been completed. It is the time operations pertaining to trackworks construction and survey conclude.

The procedure and relationship between trackworks construction and survey are as follows:

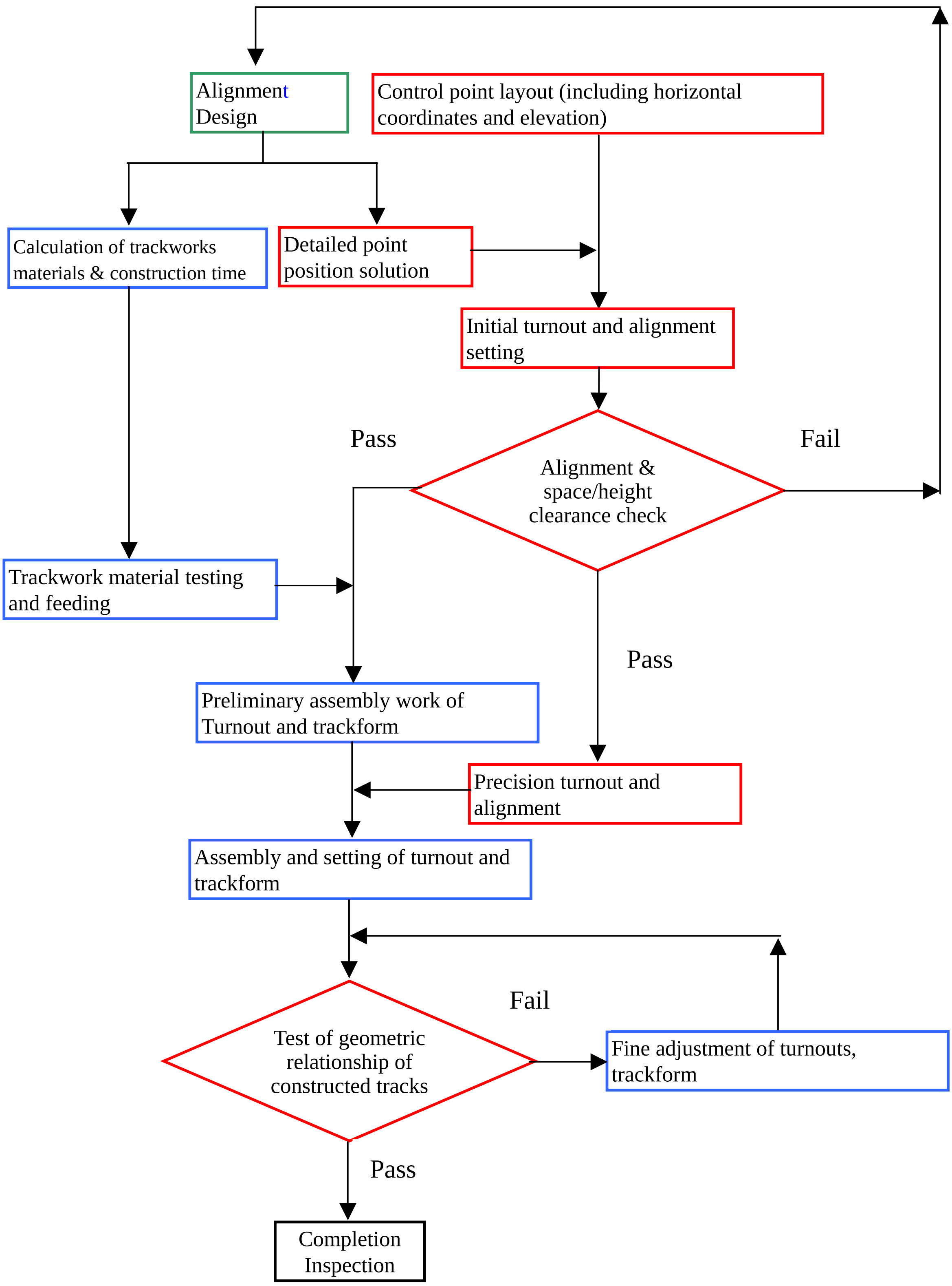

Fig.2.1 Relations of Trackworks Construction and Survey Operations

Note: Survey-related operations are circled in red;
Trackworks-construction-related operations are circled in blue.

3. TRACKWORK POSITIONING SURVEY AND TEST

3.1 Introduction of Taiwan Railway Narrow-Gauge 1067mm Track Structure

The structural characteristics of various track systems in the world are significantly different. For instance, when it comes to track surface elevation design standard, the Japanese systems employ the track center as the design standard. The cant (super elevation) is added to the outer track (1/2C) and inner track (1/2C) respectively. Meanwhile design of the Taiwan Railway narrow-gauge 1067mm track is based on the low track. The entire cant is added to the outer track. So before applying the GRP3000 track survey system, setup of track parameters will be required. Wrong parameters will result in discrepancy between the design point and the survey-determined point and give rise to mistakes. The characteristics of the Taiwan Railway narrow-gauge 1067mm track are as follows:

(1) Track Elevation Reference

Taiwan Railway Administration’s track elevation reference is based on the low track (inner track). The entire cant is added to the high track (outer track). Due to the fact that the straight line does not involve a super elevation, the left track is employed as the reference.

(2) Track Center Reference

Track center reference is based on the high track (outer track), from which the measurement is done toward the normal line direction of the low track (inner track) for 1/2G (G=1.067m). Exploration of the cause reveals the fact that the widen of gauge is totally added to the low track (inner track) results in an offset between the low track (inner track) and the track center while the high track (outer track) is still connected directly to the straight line maintaining 1/2G. Due to the fact the straight line does not have a widen gauge, the left track is adopted as the datum.

3.2 Content of Track Positioning Survey and Inspection

The purpose of track inspection is to examine whether the comparative relationship of the horizontal dimension and the elevation of the track has met the requirement of the standard. To carry out this inspection, Taiwan Railway Administration lists 5 inspection items of as-built accept tolerance in its procedures for newly constructed projects as shown in Table 3.1:

Table 3.1 Static accept tolerance for Taiwan Railway’s Newly Constructed Railroad

Inspection Items	Ballast Section	Non-Ballast Section
Gauge (㎜)	+1~-3	0~-3
Cant/Cross Level (㎜)	±4	±2

Vertical Alignment (㎜/10m)	±4	±2
Horizontal Alignment (㎜/10m)	±4	±2
Twist (㎜/5m)(not including cant decrease)	±4	±4

The inspection items are described below:

(1) Gauge

The nominal gauge of Taiwan Railway Administration is 1.067m. For the widen of gauge will be according to the regulation as required. According to Table 3.1 the gauge measured must be within 1.064m~1.068m. According to the standard of Taiwan Railway Administration, gauge measurement refers to the shortest distance between the head of rails, and 14mm below top of rail as shown in Figure 3.1.

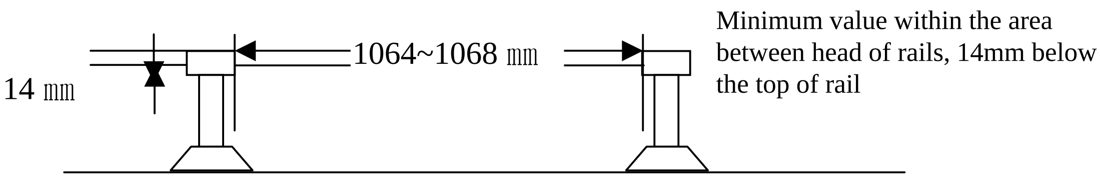

Fig.3.1 Gauge Standard

(2) Cant/Cross level

Cant/Cross level refers to the height difference between two rails of the same cross-section. Its position refers to the intersecting point between the connecting line of the 2 rail surfaces and the vertical line on the inner side of the rail. According to the cant of the outer rail, the height difference is measured. In other word, the measurement position of the outer rail is supposed to be higher than that of the inner rail. The super elevation is shown in Fig.3.2.

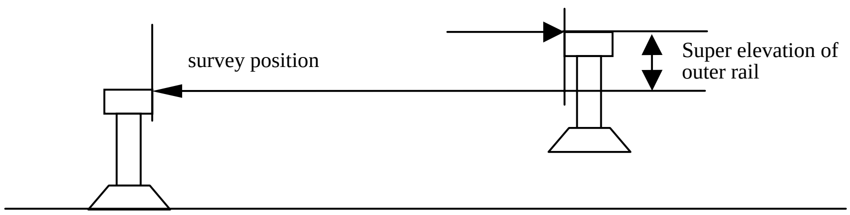

Fig.3.2 Cant/Cross level

(3) Vertical alignment

The vertical alignment survey refers to the longitudinal elevation difference of the same rail. The level of the elevation measurement point is shown in Figure 4.2. The measurement base will be the low/left rail[1]. In each measurement section of 10m in length, the inspection height difference and design height difference are compared as shown in Figure 3.3.

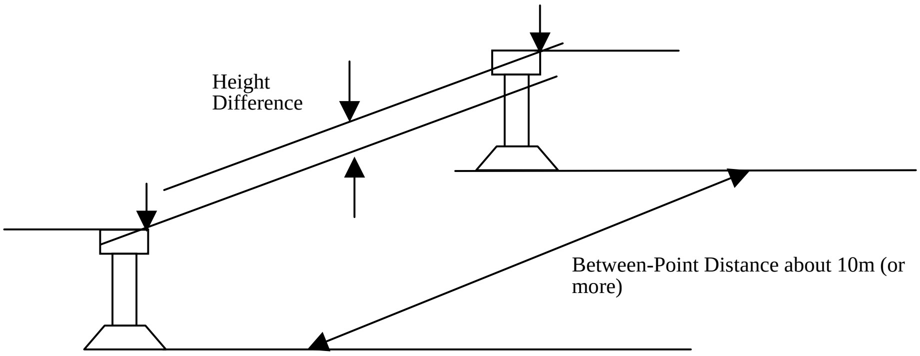

Fig.3.3 Elevation Survey

(4) Horizontal alignment

Horizontal alignment survey is about longitudinal surface smoothness of the rail. Due to the gauge widen for curved section at the inner rail, the outer/left rail or track center (533.5mm from the outer/left rail) is adopted as the measurement target. In each measurement section of 10m in length, the inspection deviation and design deviation are compared as shown in Figure 3.4.

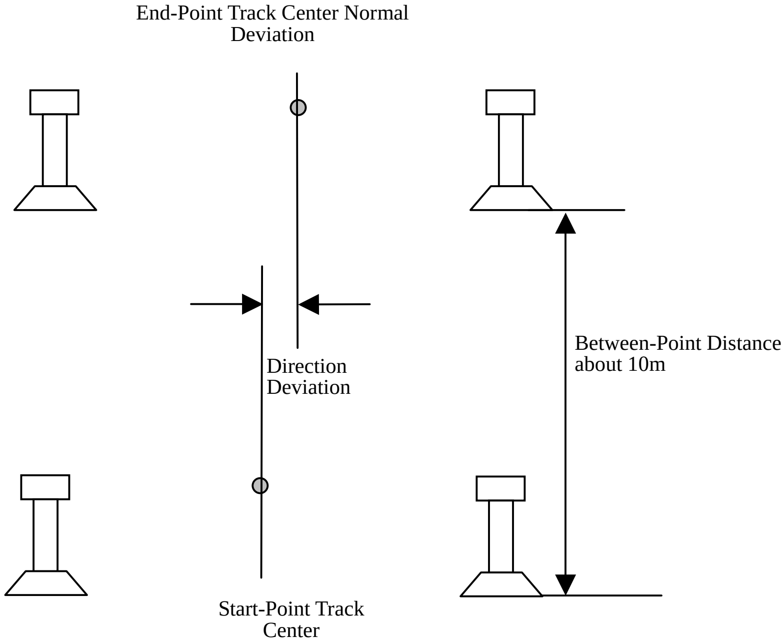

Fig.3.4 Horizontal

(5) Twist

[1] In railway, the one with lower elevation is called the inner/lower rail; the higher one is called the outer/higher rail. In the straight section (no cant), the elevations of the 2 rails are equal, and according to the direction to which is the railroad is extended they are called the left rail and right rail.

The value is a recalculation value. Referring to the horizontal difference of the plane between 2 points, it is the horizontal secondary difference. If the 2 horizontal differences are of the same direction (being positive or negative at the same time), the impact of the twist is small. If the 2 horizontal differences are of different directions (being one positive and one negative), the impact of the twist will be significant as shown in Figure 3.5.

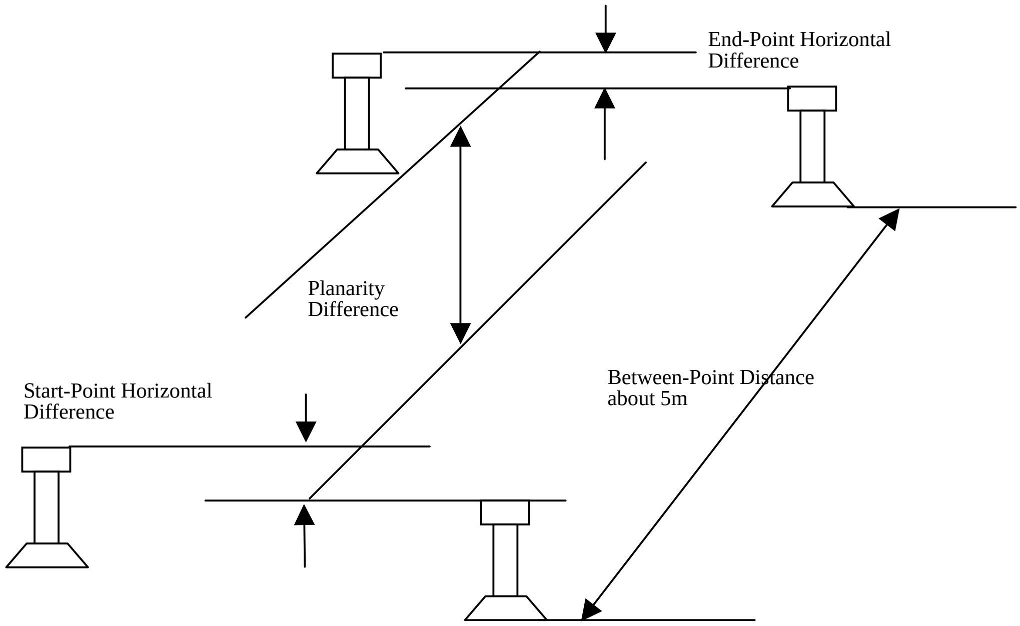

Fig.3.5 Twist

3.3 Conventional Track Positioning Survey Content & Inspection

In order to carry out the 5 inspection items above, the traditional positioning survey inspection approach first set the survey pin of the mileage point on the site for comparison against design data. The following methods are then employed for the 5 items respectively:

(1) Gauge

Traditional gauge meter is employed for measuring the gauge. The gauge widen should also be taken into calculation. The measured gauge needs to be compared with the design gauge.

(2) Cant/Cross level

Measured by level meter. The measured cant is compared with the design cant.

(3) Vertical alignment

Vertical alignment survey employs 2 level rectangular blocks (10cm in length and 3cm in height and width). A nail is tacked into the center of the square side and tied with a nylon string as shown in Figure 3.6. The length of the string is 10m. During elevation survey, the long side of the wood block is joined to the inner/left rail flat as shown in Figure 3.7 with a force of 1.5kg applied respectively to both ends. An iron meter is used to measure the elevation difference at the center (5m location) as shown in Figure 3.8 for comparison with the design value.

Fig.3.6 Elevation & Direction Measurement Device for Conventional Positioning Survey

Fig.3.7 Setup of Measurement Device for Conventional Positioning Elevation Survey at the Measurement End

Fig.3.8 Conventional Positioning Elevation Survey Method

(4) Horizontal alignment

Horizontal alignment survey is done via the same wood block. The long side of the wood block is joined to the inner side of the outer/left rail flat as shown in Figure 3.9 with a force of 1.5kg applied respectively to both ends. An iron meter is used to measure the deviation of the center point as shown in Figure 3.10 for comparison with the design positive vector of the point. When a straight section is measured, it should be half of the width of the wood block; namely, 1.5cm. When a curved section is measured, the design positive vector[2] of the section should be computed as the reference value for comparison.

[2] Extend a string between the 2 endpoints of a curve. The distance from any point of the curve to this string is called the versine of the point. Normally, the central point is adopted.

Fig.3.9 Setup of Measurement Device for horizontal alignment Survey at the Measurement End

Fig.3.10 Conventional horizontal alignment Survey Method

(5) Twist

Twist refers to the discrepancy between the horizontal differences between 2 points. It can be determined through calculation of the horizontal differences of 2 sections.

The strength of conventional survey method is that its measurement device is simple and portable. The operational team consists of only 3 persons. The survey procedure is simple, and the data can be read and analyzed right away. So filling out of standard forms is normally a part of the routine. For the 5 inspection items, the inspection points can be determined beforehand, and the design values can be calculated first for comparison with the survey values on the inspection site.

However, except the fact that certified gauge meter is used for gauge, horizontal alignment and twist inspection, the precision of elevation and direction surveys is low.

The conventional survey method is simple, but low precision is an extremely serious downside. It may be appropriate for ballast section construction and maintenance jobs, whose precision requirement is lower. Yet whether it can be applied to high-precision non-ballast track construction inspection is questionable.

3.4 GRP3000 Positioning Survey Content and Inspection

Conventional track inspection system is unable to meet the high-precision requirement of modern trackworks construction. For enhancing the precision of track system inspection, a structured track survey cart inspection system, which completes all the track inspection contents in one endeavor. Current track inspection systems developed for trackworks construction in different parts of the world can be divided into 2 types: comparative system and absolute coordination system.

The comparative system does not require the use of a coordination system. The main purpose is to examine the comparative relations of the tracks. It is unable to identify the deviation of the entire track system from the design alignment.

The absolute coordination system requires the coordinates of the inspection points of the entire control system. As a result, on the track survey cart there is a set of coordinates system corresponding to the survey points. The advantage is that through comparison with the design alignment, one can determine deviation of the inspection points of the track from the design coordinates.

Establishment of the absolute coordination system of the track survey cart is mainly done via the total station theodolite, which is situated at the control point to measure and automatically compute the inspection point coordinates, which following the calculation are transmitted to the track survey cart computer via a wireless transmission system for comparison with the alignment inputted beforehand in the track survey cart computer. The shortest difference value between the track center absolute coordinates of the inspection point and the design alignment center as the comparison point value of the inspection point. Actual operations of the GRP3000 track survey cart system are shown in Figures 3.11~ 3.16.

The track survey cart coordination system employs the coordinates identified by the prism of the track survey cart and the tangent azimuth of the comparison point to establish a coordinate system. The sensory system and structure of the track survey cart are utilized to determine the coordinates of the track survey cart at different points. To meet the 5 inspection requirements of trackworks structure, the track survey cart is able to determine the reference point of the track structure according to our criteria. Based on the elevation of the inner side of the 2 rails, as well as a length of 0.5335m from the outer rail to the inner rail along the normal direction of the track center at the comparison point, the actual track center is determined.

Fig.3.11 GRP3000 Assembly

Fig.3.12 GRP3000 Operation

Fig.3.15 Real Time Comparison between Coordinates of Station Survey and Design Lineshape for Adjustment.

Fig.3.16 Post-Adjustment Measurement. Difference from design is less than 2mm. Green indicates pass; yellow indicates over.

Corresponding to the 5 track inspections items, the inspection contents are as follows:

(1) Gauge

The sensory pole of the track survey cart is used to measure the gauge for comparison with the design gauge.

(2) Cant/Cross level

Based on the measured track center, elevations of the inner side of the 2 rails along the normal direction are determined via calculation for comparison. The result should be in line with the design cant. The value is compared against the cant.

(3) Vertical alignment

Based on the measured track center, elevation of the inner side of the lower rail (or left rail of straight sections) is determined via calculation as basis of computation. Two points about 10m away from each other in mileage are chosen for elevation calculation. The value should be compared with the design elevation of the same position.

(4) Horizontal alignment

Based on the measured track center, two points about 10m away from each other in mileage are chosen for direction difference calculation. The value should be compared with the design direction difference of the same position.

(5) Twist

Horizontal difference of track cross-sections about 5m away from each other in mileage is chosen for calculation of the horizontal difference's comparison discrepancy, which is called the twist. The value should be compared with the design twist of the same position.

All the calculated measurement values and design values above can be obtained from the track survey cart for comparison. According to the original input files the follow-up calculation formulas for the 5 inspection items are written via Excel for organizing outcomes of the 5 inspection items.

3.5 GRP3000 Inspection Example and Calculation

According to the inspection data of the track survey cart, GRP3000 through the Excel calculation formulas for the 5 inspection items converts the original absolute coordinate system into comparative track inspection in order to meet the requirement of current railroad standards.

The following case study comes from RRB Nangang Project Tender 302 Sitze Mountain Tunnel Non-Ballast Trackworks Construction Project (UK Section 17K+740~17K+800). The trackworks construction and survey of this project were both completed in 3 stages: 1. Completion of assembly of track framework; 2. Completion of non-ballast track construction; 3. Completion of final fine adjustment. Each stage is based on the 5 inspection items. Due to the fact that time constraints prevent comprehensive coverage of the vast amount of complicated data. Only the third stage, inspection of final fine adjustment, is adopted for analysis. Based on the detailed survey records, all the inspection results must meet the construction standards in order to move on to the trackworks construction stage. The 5 inspection items are described below:

3.5.1Final Inspection after Fine Adjustment

(1) Gauge

Note: 1. Error=(measure gauge – standard gauge), unit: ㎜.
2. Indication: Greater error expressed by “+”; lesser error expressed by “-”
3. Static inspection standard value: 0 ㎜ ~ -3 ㎜ for pass.

Table 3.2 Gauge Measurement Error Values

Mileage	Measured Gauge (m)	Standard Gauge (m)	Error (㎜)	Indication	Inspection
17750.094	1.066	1.067	-1	-	Pass
17755.045	1.066	1.067	-1	-	Pass
17760.002	1.067	1.067	0	-	Pass
17765.004	1.066	1.067	-1	-	Pass
17770.094	1.067	1.067	0	-	Pass
17775.057	1.067	1.067	0	-	Pass
17780.149	1.067	1.067	0		Pass
17785.051	1.066	1.067	-1	-	Pass
17789.947	1.066	1.067	-1	-	Pass

17795.190	1.067	1.067	0		Pass
17799.716	1.067	1.067	0		Pass

(2) Cant/Cross level

Note:

1. Error=(outer rail difference – inner rail difference), unit: ㎜.
2. Indication: High outer rail (error +) expressed by "+"; lesser error expressed by "-".
3. Static inspection standard value: 2 ㎜ for pass.
4. The program calculates automatically. Limited by program display and decimal constraint, the last digit may contain a 0.1 ㎜ error.

Table 3.3 CrossLlevel Difference Values

Mileage	Inner Track Difference (㎜)	Inner Track Difference (㎜)	Horizontal Difference (㎜)	Indication	Inspection
17750.094	4.3	4.4	0.1	+	Pass
17755.045	3.4	4.1	0.7	+	Pass
17760.002	3.1	5.1	2.0	+	Pass
17765.004	3.3	4.9	1.6	+	Pass
17770.094	3.1	4.3	1.2	+	Pass
17775.057	4.3	5.1	0.8	+	Pass
17780.149	4.1	5.7	1.6	+	Pass
17785.051	4.4	5.4	1.0	+	Pass
17789.947	2.5	4.4	1.9	+	Pass
17795.190	1.4	3.4	2.0	+	Pass
17799.716	1.7	2.5	0.8	+	Pass

(3) Vertical alignment

Note:

1. Error=(end-point inner rail difference – front-end inner rail difference), unit: ㎜.
2. Indication: End-point is higher (error +) expressed by "+"; lesser error expressed by "-".
3. Static inspection standard value: 2 ㎜ for pass.
4. The distance between inspection points is in principle 10M. An inspection point is selected every 5M to form paired sampling.
5. The program calculates automatically. Limited by program display and decimal constraint, the last digit may contain a 0.1 ㎜ error.

Table 3.4.1 Vertical Alignment Survey Difference Values

Mileage	Inner Track Difference (㎜)	Between-Point Difference (m)	Elevation Difference (㎜)	Indication	Inspection
17750.094	4.3				
17760.002	3.1	9.9080	-1.2	-	Pass
17770.094	3.1	10.0920	0.0		Pass
17780.149	4.1	10.0550	1.0	+	Pass
17789.947	2.5	9.7980	-1.6	-	Pass
17799.716	1.7	9.7690	-0.8	-	Pass

Table 3.4.2 Intensified Sampling Vertical Alignment Survey Difference Values

Mileage	Inner Track Difference (㎜)	Between-Point Difference (m)	Elevation Difference (㎜)	Indication	Inspection
17725.069	2.2				
17735.038	3.0	9.9690	0.8	+	Pass
17744.998	3.7	9.9600	0.7	+	Pass
17755.045	3.4	10.0470	-0.3	-	Pass
17765.004	3.3	9.9590	-0.1	-	Pass
17775.057	4.3	10.0530	1.0	+	Pass
17785.051	4.4	9.9940	0.1	+	Pass

Due to the fact that the first post-adjustment inspection result of 17785-17795 exceeds the standard value, another inspection is conducted after the second adjustment.

Table 3.4.3 Second Intensified Sampling Vertical Alignment Survey Difference Values

Mileage	Inner Track Difference (㎜)	Between-Point Difference (m)	Elevation Difference (㎜)	Indication	Inspection
17785.061	-1.0				
17795.119	0.8	10.0580	1.8	+	Pass

(4) Horizontal alignment

Note:

1. 1.Error=(end-point track center deviation-front-end track center deviation), unit: ㎜.
2. 2.Indication: Outward deviation (left/outside) expressed by “+”; inward deviation (right/inside) expressed by “-”.
3. Static inspection standard value: 2 ㎜ for pass.
4. 4.The distance between inspection points is in principle 10M. An inspection point is selected every 5M to form paired sampling.
5. 5.The program calculates automatically. Limited by program display and decimal constraint, the last digit may contain a 0.1 ㎜ error.

Table 3.5.1 Horizontal alignment Survey Difference Values

Mileage	Track Center Difference (㎜)	Distance (m)	Direction (㎜)	Indication	Inspection
17750.094	2.3				
17760.002	1.4	9.908	-0.9	+	Pass
17770.094	1.8	10.092	0.4	-	Pass

Due to the fact that the first post-adjustment inspection result of 17770-17779 exceeds the standard value, another inspection is conducted after the second adjustment.

Table 3.5.2 Intensified Sampling Horizontal alignment Survey Difference Values

Mileage	Track Center Difference (㎜)	Distance (m)	Direction (㎜)	Indication	Inspection
17770.068	4.3				
17779.995	6.3	9.927	2.0	-	Pass

Mileage	Track Center Difference (㎜)	Distance (m)	Direction (㎜)	Indication	Inspection
17780.149	4.8				
17789.947	5.6	9.798	0.8	-	Pass
17799.716	6.6	9.769	1.0	-	Pass

Table 3.5.3 Second Intensified Sampling Horizontal alignment Survey Difference Values

Mileage	Track Center Difference (㎜)	Distance (m)	Direction (㎜)	Indication	Inspection
17755.045	1.8	10.047	2.0	-	Pass
17765.004	1.8	9.959	0.0		Pass
17775.057	2.8	10.053	1.0	-	Pass
17785.051	4.3	9.994	1.5	-	Pass
17795.190	5.8	10.139	1.5	-	Pass

(5) Twist

Note:

1. Error=(end-point track center deviation-front-end track center deviation), unit: ㎜
2. Indication: Twist toward the right track expressed by "+"; twist toward the left expressed by "-".
3. Static inspection standard value: 4 ㎜ for pass.
4. The distance between inspection points is in principle 5M.
5. The program calculates automatically. Limited by program display and decimal constraint, the last digit may contain a 0.1 ㎜ error.

Table 3.6 Twist Survey Difference Values

Mileage	Horizontal Difference (㎜)	Between-Point Distance (m)	Twist (㎜)	Indication	Inspection
17750.094					
17755.045	0.7	4.951	0.6	+	Pass
17760.002	2.0	4.957	1.3	+	Pass
17765.004	1.6	5.002	-0.4	-	Pass
17770.094	1.2	5.090	-0.4	-	Pass
17775.057	0.8	4.963	-0.4	-	Pass
17780.149	1.6	5.092	0.8	+	Pass
17785.051	1.0	4.902	-0.6	-	Pass
17789.947	1.9	4.896	0.9	+	Pass
17795.190	2.0	5.243	0.1	+	Pass
17799.716	0.8	4.526	-1.2	-	Pass

4. CONCLUSIONS AND RECOMMENDATIONS

This study mainly explores the inspection type standard required for Taiwan Railway narrow-gauge 1067mm track. Through the data reprocessing method, it verifies suitability of GRP3000 absolute coordination system track survey cart for measuring relative geometric relationship between the tracks. Examination confirms that this system expedites high-precision trackwork construction. It is an especially effectively trackwork construction tool for the "non-ballast track construction project," which involves repetitive, complicate work procedures that require follow-up precision inspections and adjustments.

Data of this study indicate that conventional approach to inspection of relative geometric relationship between the tracks is both complicated and time-consuming, that the result fails to meet the requirement of high-precision trackwork construction, and that the use of absolute coordinate system track survey cart can meet this requirement. In this study, we also discover that if the inspection approach of absolute track position is employed, use of conventional approach that looks into relative geometric relationship between the tracks will be unnecessary. Furthermore, the number of inspection points can be increased. This study recommends that, taking non-ballast track for example, an inspection interval of 1.25m is appropriate for the curved section, and 2.5m for the straight section because the best support interval of the non-ballast track is 1.25m, of which the positive vector will result in high-precision outcome. Here, broken line can be seen as a curve (dependent on the radius). For ballast track, the inspection interval can be extended to 2.5m for the curved section and 5m for the straight section

Further, through the real-time comparison of GRP3000, this system can be used for precision trackwork construction. In the case of non-ballast track, adjustment may take place immediately after the inspection. In the case of ballast track, an offset is added to the deviation. The construction offset is marked on the offset pile outside the track for trackwork construction adjustment. At present the system is being gradually integrated, in hopes that it will be able to replace current trackwork construction inspection through its operational model that helps save manpower, resources and time.

REFERENCES

MOTC,1997, Railway Construction, Renovation and Maintenance Guideline, Taipei City.

China Engineering Consultants, Inc.,2004,"Taipei City Downtown Underground Railroad Nangang Extension Project – New Wudu Tunnel to Second Northern Freeway Station and Permanent Trackworks Construction Standards" , Taipei City.

Tsung-I Shen, 2003, RRB, Trackworks Construction Alignment Survey, Taipei County.

Pei-Yuh Huang, 2004,Non-Ballast Trackworks Construction and Survey, Taipei City.

Pei-Yuh Huang,2005 ,Non-Ballast Trackworks Geometric Unconformity Test, Taipei City..

RRB,2005,Railway Reconstruction Bureau Standard Operational Procedures – Survey, Taipei County.

Guo-Hsiung Cheng and Hsi Chang,2002,Trackworks Construction, Greater China Books, 2nd edition, Taipei City.

MOTC,2002,Transportation Technology Standards - 1067mm-Gauge Railway Long-Welding Track Construction and Maintenance Standards. ,Taipei City.

Taiwan Railway Bureau, 1997,Railway Construction Operational Procedures, Taipei City.

RRB,2005,Railway Reconstruction Bureau Standard Operational Procedures – Trackworks, Taipei County.
MOTC,2006,Railway Route Survey Guideline, Taipei City.

CONTACT

Tsung-I Shen
1.Section Chief
Railway Reconstruction Bureau MOTC
19F,No.7,Sec.2, Sianmin Blvd.
Banciao
Taipei 22041
TAIWAN, R.O.C.
Tel + 886-2-89691900 ext1966
Fax: + 886 2 89691826
E-mail:mty_shen@rrb.gov.tw

Che-Hao Chang
Associate Professor
Dept.of Civil Engineering
National Taipei University of Technology

Pei-Yuh Huang
Certified Surveying engineer