Application of Automatic Deformation Monitoring System for Hong Kong Railway Monitoring

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Key words: Automatic Deformation Monitoring System, TCA2003, GeoMoS, AAA values, web interfaces

SUMMARY

For the strict requirement that ensure the construction works not disturbing the daily operation of the Railway Line, automatic deformation monitoring system (ADMS) is deployed to monitor the settlement of the affected tracks. In the process of design and implementation of ADMS in railway construction monitoring, Automatic Total Station is applied for this monitoring measurement project. Software is tailored to collect data from the sensor, web interface is used for users retrieving of the result. Leica Geosystems AG developed a Geodectic Monitoring Software, GeoMoS for the total staton, GPS, meteologoical sensors and geotechnical sensors data collection. With linking to the web interface, data is displayed in adjusted graphical format. There is a analytic tools allows the numerical and graphical visualization of results and measurement. And alarm system is set, once individual monitoring points traggered the Alarm, Alert or Action (AAA) values, messages will be sent via SMS, E-mail or pagers to the Engineers for decision.There are 14 sets of automatic total station TCA2003 with Automatic Target Regonition function and the system accuracy of 1mm in 100m and those are employed to the project. There are also total 560 monitoring points those are distributed along the 1.2km railway with Tunnel, ballasted and Trough sections.

This paper focuses on the use of ADMS in railway construction monitoring, and description all the process in term of background, user requirement, system design, system implementation process, hardware and software requirement, system architecture, database structure, data output requirement, and railways work restriction in doing the automatic monitoring system work.

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1. INTRODUCTION

As a part of construction works, totally about 1.2km new railway line, is going to undertake just beside the Existing Airport Express Line. In order to ensure the construction works not disturbing the daily operation of the existing Railway Line, ADMS is deployed to monitor the settlement of the affected tracks. The total operation period were 36 months.

2. ADMS REQUIREMENT

There a number of monitoring contractors for the projects and the clients selected based on the project background, Leica Geosystems AG being the first one introduce this monitoring system in railway, first in Singapore on 1995 and second Hong Kong in 1996, and this system is very reliable for checking the daily operation work. And this project Leica provided the sensors, software, installation, test and commissioning work, a total solution to handover the client.

The project is started on first week of January 2006, and the the system implementation time are required to be running on 6-8 weeks after commissioning of the project.

Under the specifications, three sections of track are necessary to monitor, which includes Ballasted Section (600 m), Trough Section (210 m) and Tunnel Section (400 m). For the Ballasted and Trough sections, both up and down track of Railway Line are required to monitor by ADMS. For the tunnel section, only the Down Track is included. 14 units of TCA2003 and 4 spares are installed in the railways and total of 560 monitoring prisms are used. The proposed system of different section with number of prisms and total station as Table 1.

For the monitoring data, it would be served by web and that can be accessed by the client from remote site. With assistance of Leica TCA2003, GeoMoS and 560 monitoring prisms, report generated each 2 hours, daily data volume would be 6720 & total 7 million set of data in 3 years, and this ADMS system got a very strict requirement that minimum data lost if possible as the operation cost of the railway is very high due to any disturb from the existing construction work.

All these collected data, and then, will transmit to the control centre via the cables. Data will then be integrated and re-arranged under the engineer requirements. The report will be sent to all relevant persons for decision making.

3. HARDWARE AND SOFTWARE

The data capturing system is classified as an Operation part. It comprises Total Station, Reference Station Prism and Mini Prism

3.1 Total Station

There are totally around 14 sets of total station TCA2003 being deployed in the site to cover 1.2 km track. All these total stations are driven by computer automatically to trace out all mini prisms which embedded at the track side. TCA2003 can achieve +/-0.5" in angular and 1mm +/- 1ppm. The overall error budget for over 100 m in distance, it can achieve the error less than 1mm.

Due to the sensitivity of the total station, any vibration of the stand may lead to disturb the total station. We proposed that the total station will be mounted on the wall (figure 1). There are four sets of total stations will be installed at the roof of the Station. For the tunnel section, total stations will be mounted on the wall of the tunnel. At ballasted section, we proposed two sets of total station be used the pole mounted inside the noise barrier.

The power and data cable will be laid to link up all total stations which provide a channel for power supply and data transmission between the control centre and the total stations. To maintain the efficiency of the total stations, all these total station will be under service at every 6 months. 4 spare total stations were proposed for replacement during the maintenance period. Services, such as oiling and repair of servo-motor, are an essential to ensure the total station in good condition.

Meanwhile, a special lock and special security system are designed to away all the burglary of expensive equipment. The connection cables (which provided power to the total stations and data transmission) are laid along the cable trough of railway.

The position of the total stations was configured as Figure 3. For tunnel, trough and ballasted sections, 4, 4, 6 sets of total station are installed respectively.

3.2 Reference Stations for Total Stations

The reference stations are comprised pieces of prisms. They are setup in form of control network. They are distributed around the total station and installed on a comparatively stable structure. All these reference stations will be coordinated and fixed by the survey traversing. Network adjustment will be made to ensure all survey control stations are in good stand. Before each sets of measurement, all these reference stations will be observed by the total stations in order to fix the positions of the total stations.

For tunnel section, prisms inside the tunnel may be affected by the construction works as well. The survey control stations are evaluated inside the tunnel before each set of measurements. To provide a stable control network, a minimum of 6 survey control points per each total station are referenced. In facts, the accuracy of survey controls at the entrance of the tunnel is

crucial. Six fixed survey controls outside the tunnel will be referenced in order to fix the total station near the entrance of the tunnel. There are 10 numbers of 360 degree prisms (figure 4) as tie points to spread the survey controls coordinates into the tunnel. The adjustment is carried out by the GeoMoS.

Meanwhile, in order to avoid the disturbance due to the wild weather condition or damaged by the third party, we have designed a shelter for the prism. To provide the high accuracy and readabilities of the prism, these reference prisms will have regular maintenance such as cleaning and repairing.

3.3 Monitoring Points

For the monitoring points, mini optical prisms (figure 5) will be installed along the track. Under the Specification, for each track, a pair of prism will be installed in every 13m interval, i.e. at tunnel, trough and ballasted sections, about 60, 130 and 370 prisms are installed respectively. Total 560 pieces of prisms are involved in the project.

For the ballasted section, mini optical prisms are installed on the sleeper. For the tough section, since the guard rails are installed just right beside the track, there is insufficient space to place the prism on the sleeper. However, since the trough section is constructed in a U shape structure, prisms are installed at the toe of structure of the track or the base of the track structure. For the tunnel section, the mini optical prism are installed at the toe of tunnel wall. For the prism assignment, each prism would be label according to the individual total group.

To ensure the stability of survey, a special protective shelter is designed to protect the prisms. Of courses, a regular maintenance for the mini prisms is essential for the ADMS.

3.4 GeoMos Software

GeoMoS Software is the core part of this ADMS system and the GeoMoS composed essential features of Leica Sensor Manager that it can connect to and read data from different types of sensors and display the results for analysis. The Leica Sensor Manager enables new sensors to be quickly integrated into GeoMoS. The data can be stored in the database and extracted for analysis or visualized numerically or graphically. The GeoMoS software is scalable for control 14 total stations in this project and can also integrate with the temperature sensor, meteorological sensors such that to improve the quality of the measurement. For the final adjusted data, it is sent to the web interface for remote user assessed.

4. SYSTEM

The system comprised Data Capturing System, Control Workstations and Web server. Data Capturing System have already discussed in details. The Control Workstations will integrate the observations and transfer those processed data to the Web server. Through the internet, the client can get the monitoring result and also can control the workstations remotely (Figure 7).

The data will be analyzed and manipulated the data into the desire format and compared with the preset trigger value, the alarm system will activate when the trigger value is reached.

4.1 Control Workstation

4 sets of Control Workstation connect to all 14 total stations with the software GeoMoS are installed. This software can convert the observations from bearing, distance and vertical angle into X, Y and Z values. All observations taken by 14 total stations will integrate and be put into the Web server via Ethernet. To manage the whole monitoring system easily, we propose a server rack which contains 5 sets of workstation placed into a shelter at the roof floor of Olympic station to facilitate the controlling works. It got an advantage is to check the fault alarm easily while the Olympic station building can look widely over the monitoring zone.

4.2 The Alarm System

After X, Y and Z values are obtained for each monitoring prisms, further data manipulation arrangement is essential to get the meaningful result for the Engineers' decision; such as, for the single point data comparison, Alarm, Alert, and Action (AAA) values is considered. For overall analysis, by comparing the distance and levels between prisms, twist and lateral deformation of the track could be shown. While the system will be reached the designated levels, an alarm system will be triggered, a SMS message will be sent to the related person's mobile phone.

Meanwhile, the system will generate the routine report in 2 hours interval and send to related person via email. Before the train starts up every morning, a general report is sent to ensure whether the tracks are safe or not.

5. REPORT FORMAT

The system could generate the following types of report:

- Tabular & Plots Report
- Alarm System

Tabular Report includes all data in the table format to show the settlement details. The monitoring data is tabulated in text format. Information like initial reading, real time observed reading and their differences in X, Y and Z is shown. In figure 8 -10, the changes of a single epoch (Prism No. 135) in 5 days are shown.

The specific chainage for their movements or the overall settlements can be studied and the systsm plot AAA values into the plots as a reference to study the trend. Based on all X, Y & Z data, we can analyse the degree of deformation under different aspects.

According to the client specifications, the system should allow the automatically alarm system once the settlement reach the AAA values. The GeoMoS has this option module for the user.

The alarm system will automatically send a message via SMS to all related party who includes the on-site surveyor. In occurrence of triggering alarm, the surveyor examined whether it is a fault alarm or not, and a brief message is sent to related party.

6. SUMMARY AND CONCLUSIONS

This paper presented the design and implementation of ADMS in the typical railways and tunnel area. Experiences in construction project of railways in Hong Kong , it is necessary to employ an auotmatical monitoring system to fulfil the strick railway monitoring requirement in 24 hours a day.

ADMS allows measurement, analysis and alarms in real time and it running 24 hours a day, 365 days a years. It is a very flexible system in adaptoring the railways and tunnel site monitoring in complemented of the geodetic sensors like strain gauge for Engineers inteprlataion and the Engineers back on the real time result and quickly take an appropriate decision in advance.

REFERENCES

Karl Sippel (2000). Modern Monitoring System Software Development. Leica Geosystems AG.

Leica Geosystems AG. (2001). Automatic Monitoring Systesm for the ”Linea 9” extension of the Barcelona Underground System.

Table 1. The Number of TCA2003, Prisms and GeoMoS Software

Sections	**GeoMoS**	**Monitoring Prisms**	**TCA2003**
Tunnel Section	One copy of GeoMoS	400 meters – 60 Prisms	4
Ballasted section	Two copies GeoMoS	600 meters – 370 prisms	6
Trough section	One copy GeoMoS	210 meters – 130 prisms	4

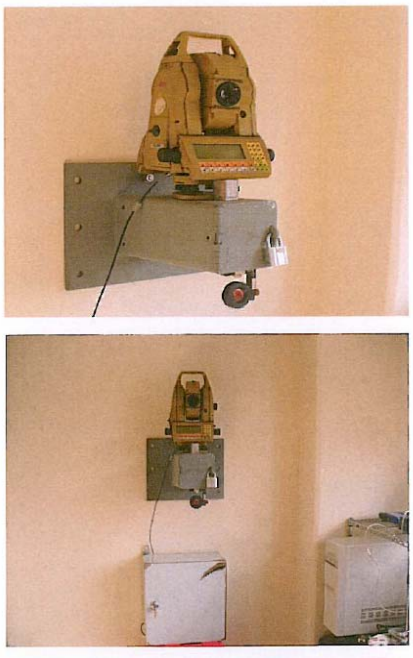

Figure 1a&b Wall Mount

Figure 2 Pole Mount

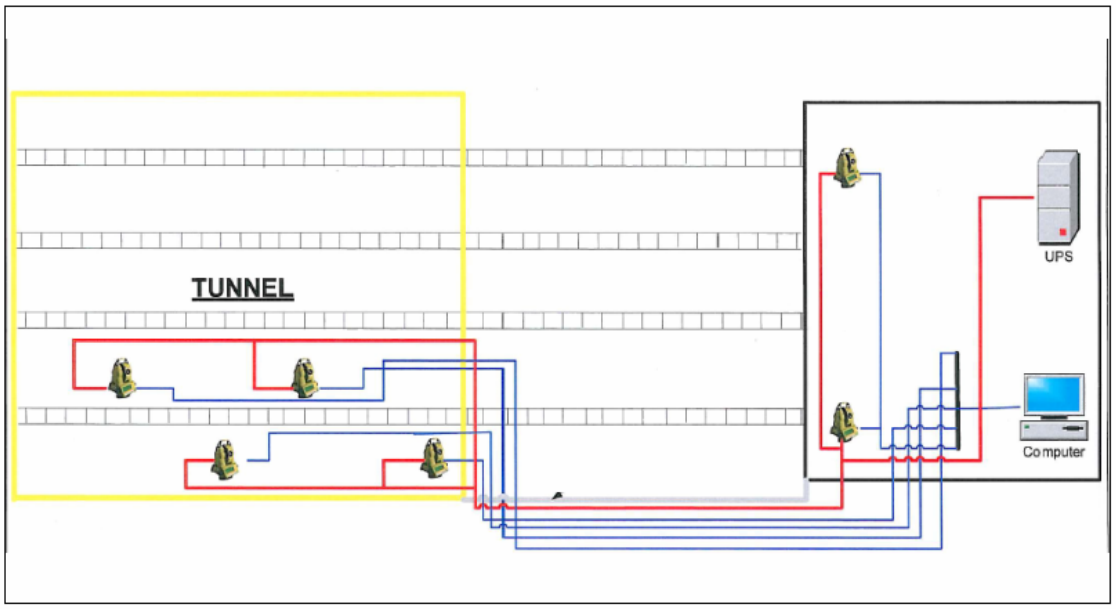

Figure 3 Total Station Configuration

Figure 4 360 degree prism

Figure 5 Mini Prism with protective shield

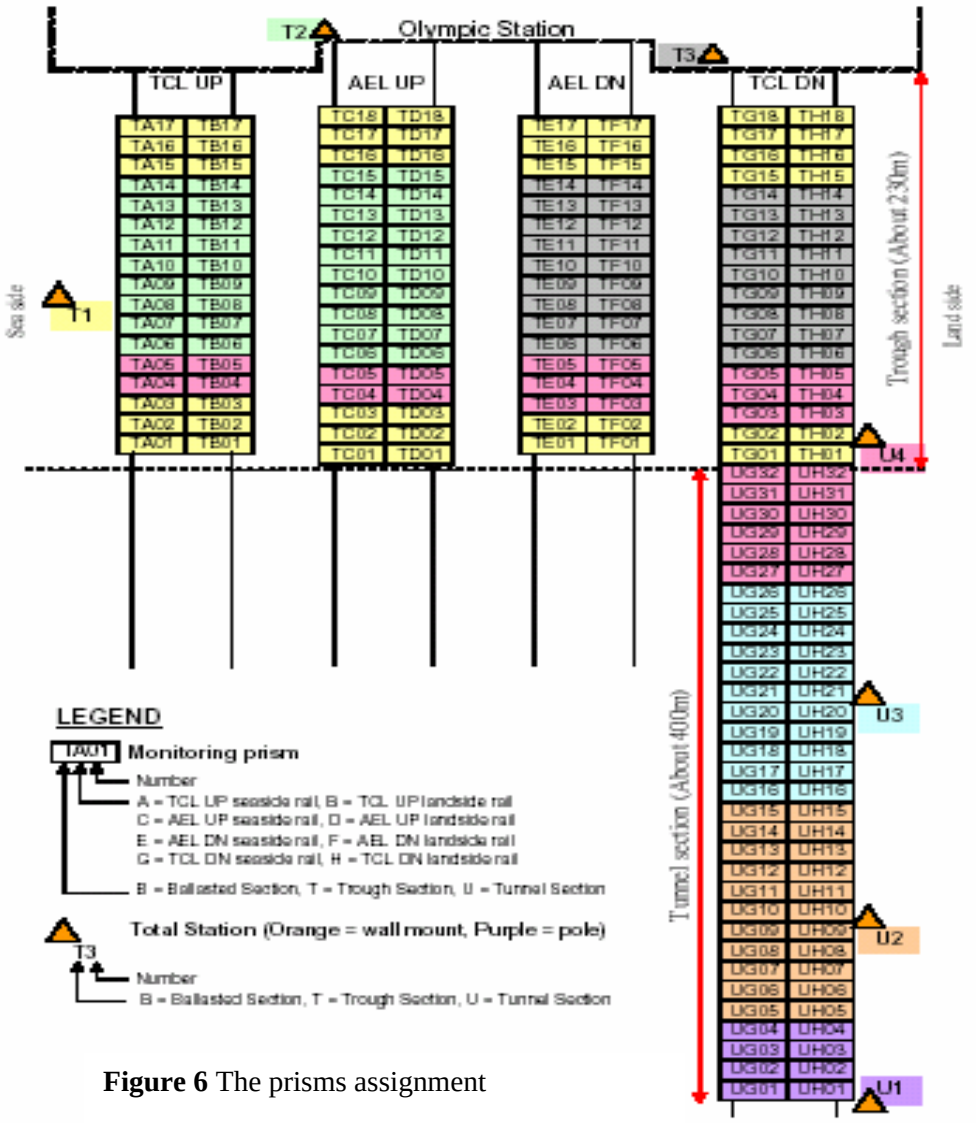

Figure 6 The prisms assignment

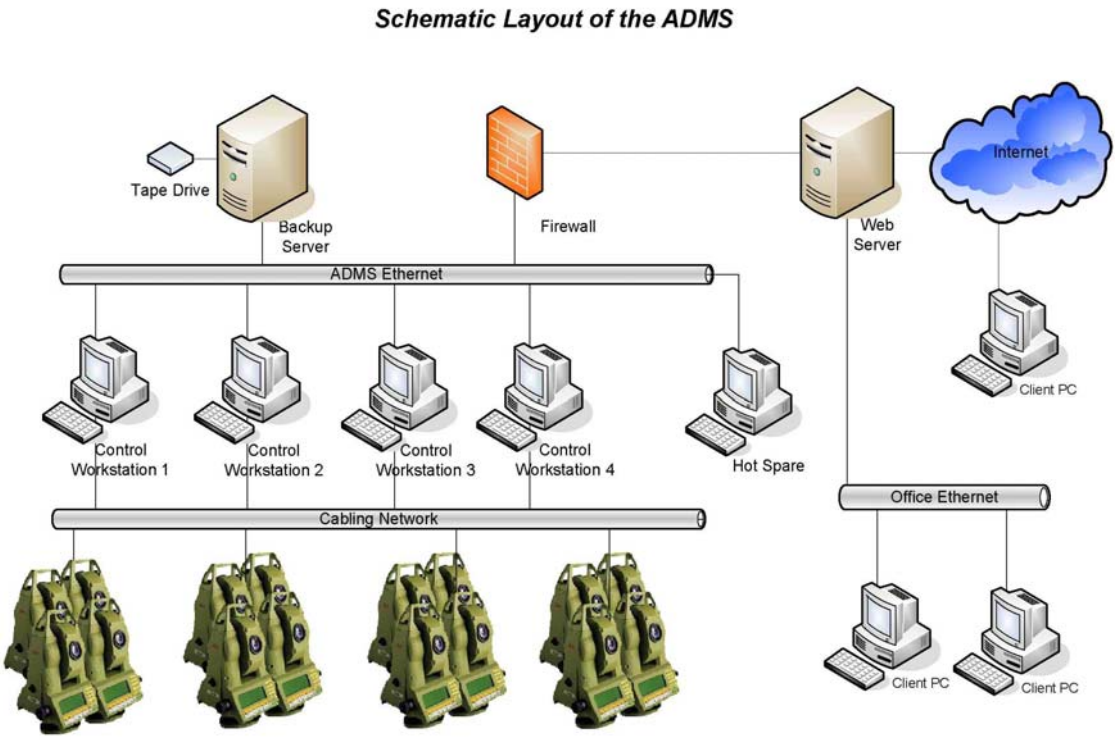

Figure 7 ADMS Schematic Diagram

Prism No:	135				
Location	CH1092 Uptrack West				
Epoch	Z-value	Settlement	Alert	Action	Alarm
13/02/02 18:00	1.3550	0.0000			
13/02/02 22:00	1.3570	0.0020			
14/02/02 02:00	1.3560	-0.0010			
14/02/02 06:00	1.3555	-0.0005			
14/02/02 10:00	1.3567	0.0012			
14/02/02 14:00	1.3560	-0.0007			
14/02/02 18:00	1.3561	0.0001			
14/02/02 22:00	1.3568	0.0007			
15/02/02 02:00	1.3559	-0.0009			
15/02/02 06:00	1.3549	-0.0010			
15/02/02 10:00	1.3548	-0.0001			
15/02/02 14:00	1.3549	0.0001			
15/02/02 18:00	1.3553	0.0004			
15/02/02 22:00	1.3560	0.0007			
16/02/02 02:00	1.3554	-0.0006			
16/02/02 06:00	1.3555	0.0001			
16/02/02 10:00	1.3547	-0.0008			
16/02/02 14:00	1.3545	-0.0002			
16/02/02 18:00	1.3557	0.0012			
16/02/02 22:00	1.3562	0.0005			
17/02/02 02:00	1.3554	-0.0008			
17/02/02 06:00	1.3542	-0.0012			
17/02/02 10:00	1.3552	0.0010			
17/02/02 14:00	1.3423	-0.0129			

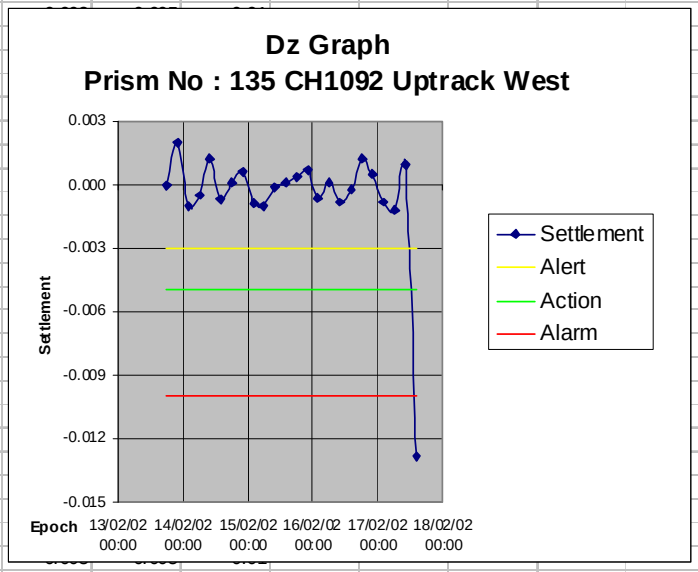

Figure 8 The Sample Tabular Report

Chainage	Initial	Previous	Current	Curr-Init	Curr-Prev	Alert	Action	Alarm
1000	1.3550	1.3450	1.3450	-0.0100	0.0000	-0.003	-0.005	-0.01
1004	1.3570	1.3554	1.3540	-0.0030	-0.0014	-0.003	-0.005	-0.01
1008	1.3560	1.3530	1.3540	-0.0020	0.0010	-0.003	-0.005	-0.01
1012	1.3555	1.3571	1.3560	0.0005	-0.0011	-0.003	-0.005	-0.01
1016	1.3567	1.3562	1.3510	-0.0057	-0.0052	-0.003	-0.005	-0.01
1020	1.3560	1.3534	1.3500	-0.0060	-0.0034	-0.003	-0.005	-0.01
1024	1.3561	1.3553	1.3490	-0.0071	-0.0063	-0.003	-0.005	-0.01
1028	1.3568	1.3574	1.3490	-0.0078	-0.0084	-0.003	-0.005	-0.01
1032	1.3559	1.3542	1.3532	-0.0027	-0.0010	-0.003	-0.005	-0.01
1036	1.3549	1.3522	1.3510	-0.0039	-0.0012	-0.003	-0.005	-0.01

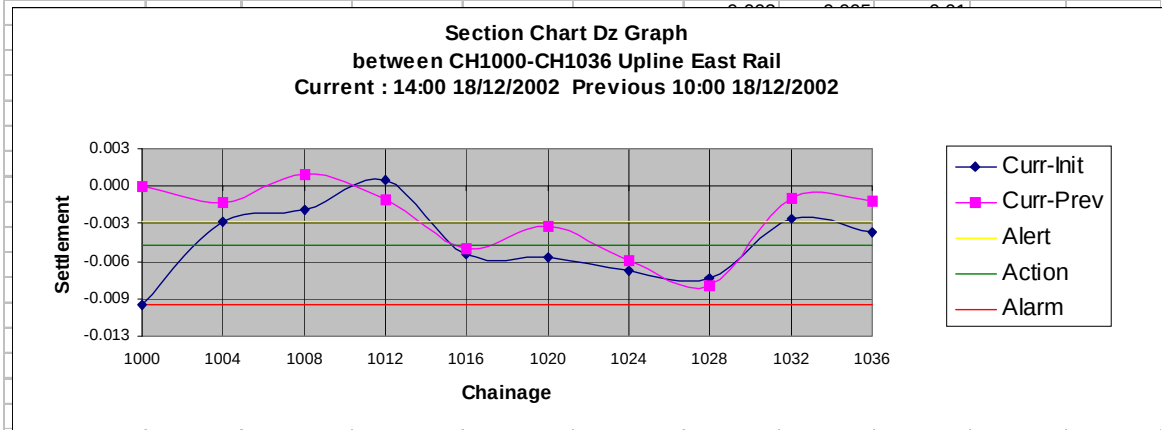

Figure 9 The plot of Chainage vs Settlement

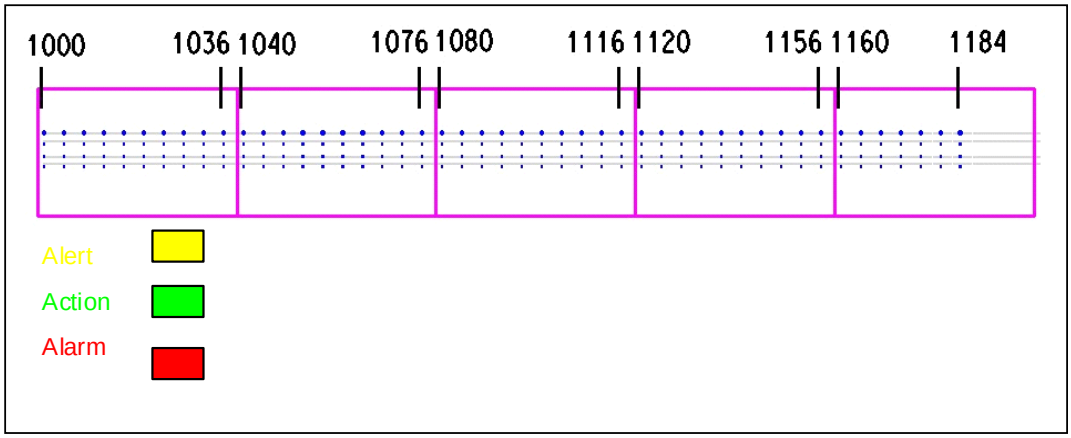

Figure 10 The settlement at an instance along the track

BIOGRAPHICAL NOTES

Eric Tang is the Managing Director for the Eric Tang & Associates of Hong Kong, running the multi-disciplines business in Land Surveying Field. Eric is current conducting a number of Monitoring Projects in the area Railways, Tunnel, Highways and Building with application of GPS, Automatic Total Station and various Geodetic Sensors. Eric has over 15 years of experience in topographic surveys, hydrographic surveys, land boundary surveys, monitoring surveys, condition survey, pipeline survey, engineering works in reclamation, dredging, trenching, construction of seawall, railway and highways in Hong Kong and China.

Vincent Lui is the Sales Manager and Technical Specialist at Leica Geosystems Hong Kong office. Vincent is currently developing a GPS network infrastructure and a number of positioning services and systems in Hong Kong that serve for many applications including deformation monitoring in the area of subsidence, landslide, bridge, water dam and high-rise building. Vincent has over 11 years of experience in the field of GNSS, navigation, reference station infrastructure and tunnel & subsidence monitoring in Hong Kong and China.

Andrew Wong is the Product Manager at Leica Geosystems Hong Kong office, working with area of 3D Laser System Applications & Structure Monitoring Survey Instrumentation and he is specialized in Surveying Automation and Monitoring Sensors Applications. Andrew has over 18 years of experience in the field of Engineering Surveying, Monitoring Sensors, Hardware and software integration in Monitoring Project Implementation in Hong Kong and China.

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