For discussion
5 January 2012

Legislative Council Panel on Transport

Applications of Latest Surveying Technologies in Major Road Works

Purpose

This paper briefs Members on the applications of the latest surveying technologies on road construction and maintenance works in the Highways Department (HyD), including global positioning system (GPS), automatic monitoring survey system (AMSS) and three-dimensional laser scanning.

Background

2. With Hong Kong's economic growth and improved quality of life, demand for public transportation has been continuously increasing and the construction and maintenance of roads have become very important. The HyD has been actively involved in improving the road network development while at the same time maintaining the roads, making sure that the existing road network can meet the transport needs of social and economic development. Road construction requires accurate surveying data for planning of routes, positioning of structures and computing of earthworks, etc. Road maintenance also relies on accurate surveying technology for continuous monitoring and grasping the conditions of all road facilities.

3. The HyD has been keeping abreast of new surveying technologies for enhancing surveying accuracy and for smoothening works in road design, construction and maintenance. With the advancement in technology, more automatic and sophisticated surveying instruments are available for use in surveying. The new technologies have brought about obvious improvements to surveying accuracy, operation efficiency and personnel safety, which are difficult to achieve with conventional surveying techniques. This paper will explain how the HyD has been deploying GPS, AMSS and laser scanning technologies to support positioning activities involved in road construction and maintenance projects over the years. The activities include route planning, alignment

design, construction setting-out and checking, structure movement survey and settlement monitoring, as well as emergency survey.

(I) GPS

4. In brief, the GPS consists of 24 satellites. The satellites travel at known orbits some 20,000 km above the Earth and broadcast signals continuously. A receiver can obtain signals from the satellites and measure its own position to varying degrees of accuracy. A GPS survey can be operated in either a stationary or mobile mode by relative-positioning. A single GPS receiver working on its own may only achieve a positioning accuracy in the order of tens of metres. In order to meet the accuracy requirement in engineering surveys, surveying staff use two receivers in relative-positioning in GPS survey, so as to eliminate numerous errors in receiving satellite signals caused by instruments and the atmosphere. Such arrangement enables accurate determination of positions to a few millimetres. Relative-positioning can be operated in either static or real-time kinematic mode (as illustrated in **Figure 1 of the Annex**). Positioning accuracy in the order of +/- 5mm can be achieved in the static mode, but it takes a longer observation time. On the other hand, in the real-time kinematic mode, accuracy in the order of +/- 20mm can be achieved in a matter of seconds. The two relative-positioning techniques have been widely adopted in various engineering surveys to meet different accuracy requirements.

(A) Application in Mega-scale Projects

5. GPS is particularly useful in cross-boundary highways projects. These mega-scale highway projects are usually located in remote locations and cover extensive areas where adequate reliable surveying reference stations may not exist in the vicinity. Taking the Shenzhen Western Corridor as an example, during the design and construction of the Corridor which connects lands of two different coordinate systems in Hong Kong and the Mainland, the GPS technology was used in the establishment of an independent surveying control network for the project with six control stations on each side of the Deep Bay area. Similarly, the technology is also used widely in the Hong Kong-Zhuhai-Macao Bridge project. With full collaboration among the Mainland, Macao and Hong Kong stakeholders, a total of 16 control stations (eight in Zhuhai, two in Macao and six in Hong Kong) have been established by GPS surveying techniques around the Lingdingyang area for the provision of an accurate positioning framework for the detailed design and construction of the

Bridge. Furthermore, Continuously Operating GPS Reference Stations (one in Hong Kong and two in Zhuhai) have been established in the project to provide fast and accurate positioning information to support the necessary piling, reclamation and subsequent construction works in the open water.

(B) Application in Monitoring of Bridge Structural Conditions

6. Movements and deflections in response to varying loading conditions, among others, are useful indicators on the structural conditions of bridges. Continuous collection of accurate position data, which has been made possible through application of GPS technology, would help monitor bridge conditions. GPS receivers have been installed in different locations such as the bridge towers and deck surfaces of the Tsing Ma Bridge, the Kap Shui Mun Bridge, the Ting Kau Bridge and the Stonecutters Bridge to provide real-time data on lateral and vertical movements of the bridges to engineers for detailed studies of their structural conditions.

(C) Application in Data Collection under Adverse Weather Conditions

7. The application of GPS enables collection of position information under all weather conditions. During the construction of the Stonecutters Bridge, for example, it was necessary to ensure that movements of the suspended bridge deck were within design limits at all stages during construction even under strong wind conditions. Otherwise, the structural integrity of the deck units might have been impaired. In September 2008 on the approach of typhoon Hagupit, being mindful of the impossibility of carrying out conventional surveying operations and collecting movement data under typhoon conditions, two GPS receivers were promptly secured onto each of the suspended decks for tracking their movements before the arrival of the typhoon. The four receivers managed to collect a set of movement data over the period confirming that the movements were within design limits under the adverse weather conditions when the typhoon was nearest to Hong Kong. The construction of the Stonecutters Bridge was finally completed in April 2009 and opened for traffic in December 2009.

(D) Other Applications

8. The GPS technology is highly efficient in capturing large amount of position information with reasonable accuracy. Apart from the above applications, the HyD also uses GPS in topographical surveys and in collecting asset information on street furniture such as lamp posts, street name plates and manhole covers in areas of open sky window. The street furniture data together with their attribute information are useful for the keeping of comprehensive asset inventory and planning of repair and maintenance works.

(II) AMSS

9. The AMSS consists of a number of total stations connected together to a computer for taking survey observations to fixed targets at pre-defined intervals. A schematic diagram of AMSS is shown in **Figure 2 of the Annex**.

10. Each total station in the system is first arranged to go through its observation sequence manually. Afterwards, with the automatic target recognition function, the total stations will perform automatic tracking, pointing, taking angle and distance measurements and recording according to a preset time schedule. The AMSS can automatically point and take angle and distance measurements of many targets in one go. Once an AMSS is set up and secured, the system can be left on site to take measurements on its own. Such system is very suitable for difficult environments such as dangerous slopes, saving the risk of deploying personnel to such environment.

11. The AMSS is highly accurate and is capable of achieving a precision of +/- 1.0 mm and +/-0.5” in distance and angle measurements respectively. All measurements collected can be processed and displayed in graphical form by computer in the field. Furthermore, alarm can be activated if the detected movement exceeds the allowable tolerance. The system has been deployed to many highway projects with monitoring needs, for example, monitoring of rock anchor and retaining wall movements. When anomaly occurs during measurement, the AMSS system will record the time and level of the anomaly, and produce the related warning messages to alert surveying staff for follow-up action.

(III) Three-dimensional Laser Scanning

12. Three-dimensional laser scanning is a contact-free measuring technique. A laser scanner can collect position data with a high density of points (dense point-clouds) of the object. From each measured point in the point-cloud, its position in terms of x,y,z co-ordinates can be calculated. With further processing, a digital three-dimensional model of the object can be constructed. The laser scanner emits lower-power light pulses and the travel time of the light pulses to and back from the object is measured. The scanning speed is around 4,000 measurements per second. The effective scanning coverage is 360° horizontally and 270° vertically with an effective range of 130 metres. A built-in camera allows automatic texturing of the individual scans, and from the scans a three-dimensional photo-textured model that is measurable and with rich details that can be generated. The three-dimensional model can further be viewed in two-dimensional plans and/or sectional drawings for a variety of purposes.

(A) Application on Detection of Road Surface Unevenness

13. For repair and maintenance works of roads, a scanner can be deployed to locate road surface defects (e.g. road unevenness and local settlements). These defects are sometimes difficult to be identified with naked eyes and it will take a longer time to locate if conventional surveying techniques are employed. Closure of road for conventional surveying works, causing interruption to traffic flow and upsetting safety to road users, may not be an option in many of the cases. The laser scanning technology works very well for works of this nature since its operation can avoid any road closure at all and the required data can be collected within a short duration.

(B) Application in Surveying of Failed Slopes and Damaged Roads

14. In June 2008 laser scanner was deployed to Lantau to measure the damage to the Keung Shan Road caused by the adjacent slope failure during heavy rains. A photograph showing the site condition is included in **Figure 3 of the Annex**. At the scene, the scanner was positioned at a place overlooking the failed slope. It finished the scanning work in a matter of hours. The whole operation did not require surveying personnel to work on the failed slope or the loose debris, thus ensuring

safety of the staff. The point-clouds collected were eventually processed to form a digital terrain model for estimation of the volume of earth failed and for engineers to work out the remedial measures.

(C) Other Applications

15. Over the years, three-dimensional laser scanning has been used in many other surveying tasks. Examples are measuring the headroom of overhanging power lines on expressways, surveying the damages to the pavements caused by trees with overgrown roots, identifying surface deformation of retaining structures, and mapping those structures/features that are hard to access but important to engineering designs.

Advantages of Applications of New Technologies

16. Applications of the new technologies in surveying tasks mentioned above are more effective than conventional methods. For example, the application of GPS in the Shenzhen Western Corridor project has accurately established an independent survey control network of six far apart control stations in the Hong Kong area within three days, which is less than half of the time required by conventional surveying methods. In a case of a retaining wall monitoring, the AMSS also saved more than one third of the manpower to complete the survey within a comparable period of time when compared to using conventional methods. As for three-dimensional laser scanning technology, the manpower to complete the same road survey using conventional methods is estimated to be about three times compared to using laser scanning. In addition, the need for road closure in conventional methods will also cause inconvenience to road users. Three dimensional laser scanning technology can avoid the above problems, and increase the work efficiency while maintaining convenience to road users.

17. On the other hand, the various new technologies can enable a safer environment and higher efficiency in surveying works. As mentioned above, under adverse weather conditions, surveying tasks may not be able to be completed by conventional methods. New technologies such as the application of GPS allows surveying staff to gather survey data and perform monitoring surveys under adverse

weather conditions and at the same time avoids the danger of staff working in adverse weather conditions. Without the aid of the new technology, surveying staff will have to spend a great amount of time to review the impact on road structures under adverse weather conditions. Application of the AMSS and three dimensioned laser scanning technologies can enhance work efficiency in monitoring surveys and at the same time greatly reduce the need for survey staff to work in difficult environments. There are also places that are difficult or dangerous for surveying staff to access and work in, such as steep slopes or failed slopes. Without the aid of the new technologies, surveying work will be very difficult to conduct; and if only conventional surveying methods can be used, much more time and staff resources have to be spent.

Way Forward

18. The HyD will continue to keep itself abreast of the latest technologies available in the surveying industry and make use of them as appropriate in delivering our highway surveying services for the benefits of the Hong Kong community.

Highways Department
December 2011

Annex

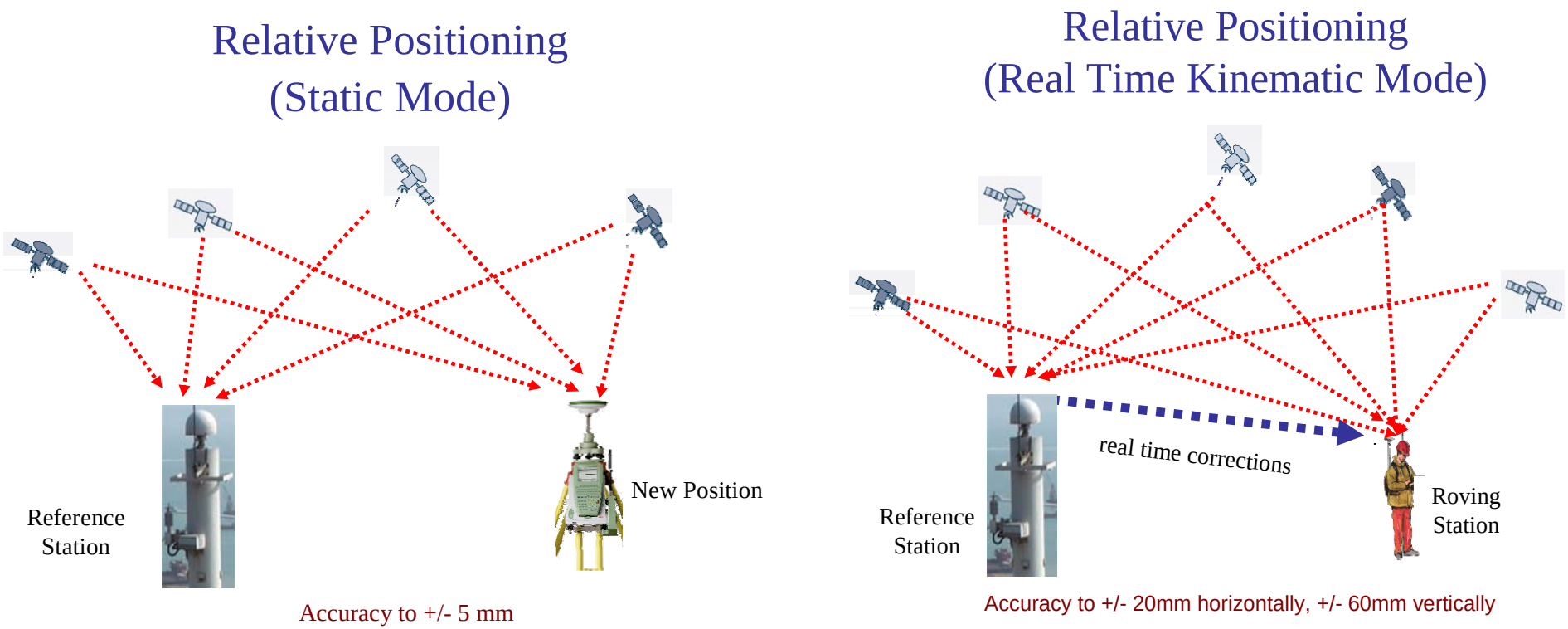

Figure 1 The Two Commonly Used Relative-positioning Modes

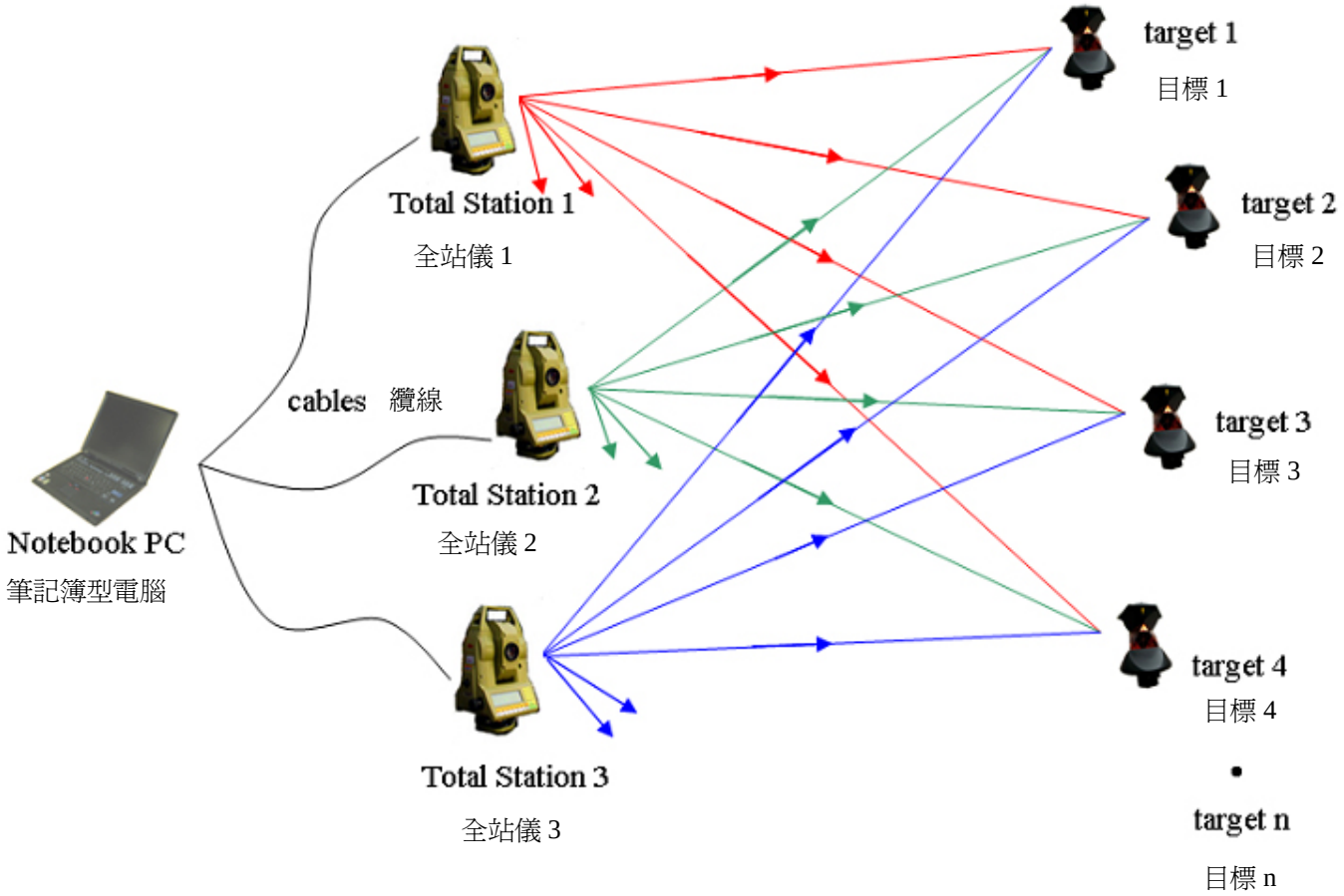

Figure 2 A schematic diagram of the Automatic Monitoring Survey System

Figure 3 The Laser Scanner at Work on Keung Shan Road