Study on the Application of GPS to Monitoring Land Subsidence

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Abstract

There are many problems which takes long time and lots of work to monitor land subsidence by traditional method. These problems can be solved by GPS. Combining with the field example, this paper studies the application of GPS to monitoring land subsidence, analyses the advantages and errors of GPS survey method, and puts forth the suitable conditions of monitoring land subsidence by GPS.

Key words: GPS; error; measurement; land subsidence

0. Introduction

Land subsidence is a main type of widely and seriously geological disaster. To monitoring land subsidence by traditional measurement, there will be a big workload, long period, not timely and veracity. With the development of GPS technique, the monitoring method united GPS with leveling has many advantages, like little restrictive conditions, short surveying period, laborsaving, cost saving, efficiently, etc.

1 Design of GPS network

1.1 Design principle of GPS network

In generally, the GPS network has been designed as the closed graph constituted by independent observation line. Triangle network has good geometry structure and nice self-checking ability; it can discover the gross error of observation successful and ensure the dependability of the net. At the same time, the precision of the baseline vector in the midst of the neighbored point in the adjustment net is equably distributed. So the triangle net has been used in our actual GPS net contained seventeen triangles.

In order to determine the orthogonal heights of each point, it must be choose no less than three benchmarks to restrict the height commonly and distributed equally in the net. In this surveying of GPS, the point of GPS and the primary horizontal control point must be superposed by all means to confirm the transition parameters of the GPS network and the horizontal network. The coordination of G and H point in the GPS network is known. All points except number J5、J10 are observed GPS heights and level elevation.

1.2 The principle of point location

Owing to that the observation stations is not demanded to be visible each other, the point location is easier than other classical surveying. So the GPS network form is very agility. But the work to locate the GPS point affected the whole surveying work greatly, the relative information must collected sufficiently, the GPS points must located on actual exploration and treated by some methods.

In order to escape the disturbing by the magnetic field to the GPS signal, the observation station should be set up far away the high-power microwave station and the high-pressure wire. In order to avoid or decrease the multi-path effecting, the observation station should keep away from the topography and landform where a strong reverberation to the electromagnetic wave signal has. The observation station should be established at traffic convenience place, easy to observe combined with other survey method and expand, and also away from large bridge, highway, and machine workshop in order to escape the effecting of vehicle-pass, machine operation and decrease the observation precision.

The observation station should be located at widen visible and easy fix equipment place. The elevation angle of the circumambient barrier less than 10° ～15° . In the actual control network, many triangulation point have targets, it shield a part of electron magnetic wave. If the GPS receiver was set in it to do surveying, it will effect to receive the satellites signal directly, give birth to loss of lock easily, have difficulty to positioning. Therefore, when the GPS point meet with target, we should fall the target or change the point position or set up assistant point.

When the ambience of the monitoring point is not favorable to observing, we could set up permanent monument nearly as the GPS observation point. The height must be determined united with leveling between the observation points and the monitoring points. In our actual observation, the height of number J7, J5, G and H are determined by this method.

1.3 The instrument selection

We select three GPS receivers of double frequency, 5 mm + 1 ppm nominal accuracy to survey, use the SoftSurv software developed by Novatel Company to down load the observation data, and use the GPSurvey software developed by Trimble Company to calculate the baseline and adjust the GPS network.

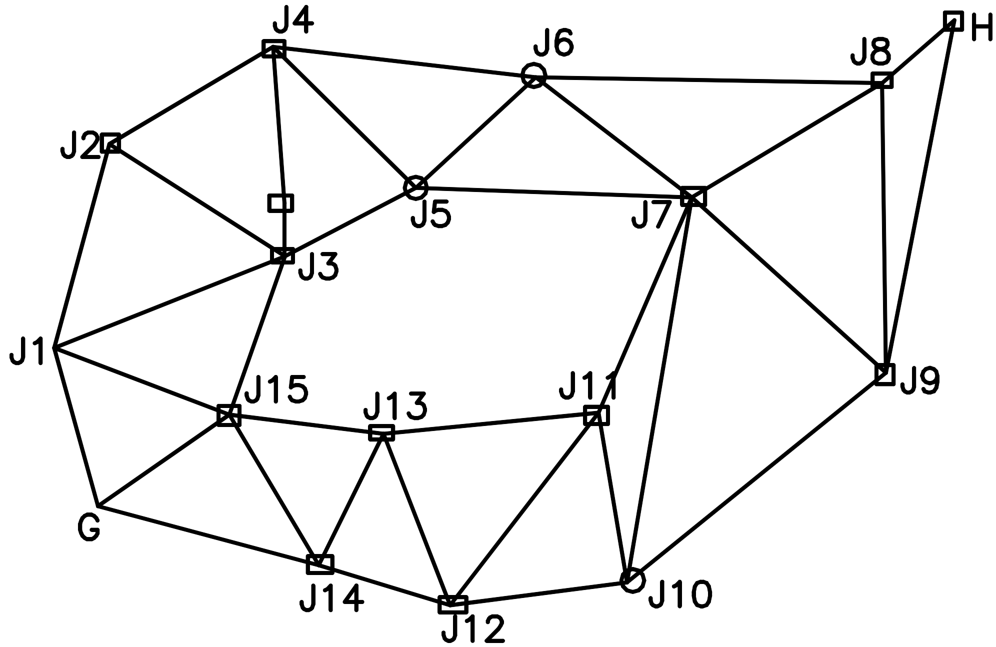
There are various of GPS equipments worked usually among -50～70 ℃ temperatures. The temperatures in the surveying process will affect some equipment. To improve the accuracy, we should take steps to reduce temperature or keep temperature.

2 Field example of using GPS to Monitor Land Subsidence

2.1 Basic introduction of GPS network

This GPS network is E grade contained with 17 triangle simultaneous circles setting up by 17 GPS points. The subsidence points selected have credible elevation.

The points in GPS network distributed showing in figure 1. The detailed statistics data about the GPS network listed in table 1.



□ Point of GPS with leveling ○ Point of GPS

Fig.1 The GPS network

Table 1 Statistics data of GPS net

Grade of GPS network	Number of points	Number of Baseline	Number of simultaneous circles	Length of the longest line (Km)	Length of the shortest line (Km)	Average length of lines (Km)
E	17	34	17	6.5	2.0	3.7

2.2 Field observation

The space geometry distributing of the GPS satellites has a large affection to the precision of positioning. In order to select the best period to observation, the latest ephemeris documents (not excised 30d) need to download. The number of the visible GPS satellites and the variety relevant value of PDOP in the condition of around the fixed coordinate point about 300 km and elevation angle bigger than 15° can be obtained with the software which can process the ephemeris document. According to the everyday workload and the surrounding condition of the GPS points, GPS surveying could be take on the more than 5 satellites and less than 10 PDOP. It should observe in the periods of large number satellites and small PDOP values.

After arriving at the GPS point, the antenna should install flat and center strictly, the panel of receiver towards north. The height of the antenna should be measured forward and after observation with the ±3 cm differences. Assure the simultaneous observation time between turn on and turn off to the fieldwork observation plan. During the surveying, taking strict precautions against move equipment, holding up signals. When meet the special condition you should notice others at other observation station timely to end or extend the time of observation. When the survey finished, transit the data to notebook timely, calculate baseline, test the quality, and insure the correctness and reliability of data.

2.3 Data processing

After the field observation, the observation data should be analyzed in time. In this progress, the rate of data eliminates less than ten percent. After the baseline calculation, checkout the quality of all the fieldwork data mainly as follows:

Closure detection Suppose that W_X, W_Y and W_Z is the coordinate sect closure on the direction X, Y and Z in the close circle, WS is the tolerance of the close loop's closure, and n is the number of the lines in the close circle, σ is the standard deviation as the order of correspond level. Synchronous circle closed difference (listed in table 2) should be satisfied as:

$$W_X, W_Y, W_Z \le \frac{\sqrt{3}}{5}\sigma \quad (1)$$

Asynchronous circle closed difference should be satisfied as:

$$W_X, W_Y, W_Z \le 3\sqrt{n}\sigma; W_S \le 3\sqrt{3n}\sigma \quad (2)$$

Consider the borderlines consisted as the asynchronous circle, the Asynchronous circle closed difference listed in table 3.

Table 2 Synchronous circle closed difference

	Length (m)	Wx (m)	Wy(m)	Wz(m)	σ (m)	$\sqrt{3}\sigma$ /5(m)
Max	6740.769	0.0001	0.0003	0.0001	0.0084	0.0468
Min	16114.822	0.0129	0.0138	0.0220	0.0169	0.1120

Table 3 Asynchronous circle closed difference

Total	Accuracy	Baseline	Wx (m)	Wy(m)	Wz(m)	$3\sqrt{n}\sigma$ (m)
44907.299	0.8982	11	-0.0206	0.0058	0.0007	8.937

Difference of baseline re-observations

The difference between any two periods of the same line should be less than $2\sqrt{2}$ times of standard precision of the receiver. In our GPS network, there are 9 repeat baseline, the difference between each other is 0 to 0.008 meters, σ is about 0.0055 to 0.0082 meters.

The quality control index of the baseline calculation are mainly rate of data eliminate, RATIO, RDOP, RMS, synchronous circle closed difference, asynchronous circle closed difference and the difference of baseline re-observations, etc. Among them, the quality index like RATIO、RDOP、RMS only have some relative meaning, the value can not illuminate the quality of baseline absolutely. If the RMS is bigger, it shows that the quality of the observe value is bad. If the RDOP is bigger, it shows that the condition of observation is not perfect. At the process of the baseline treatment, select the best value to calculate the closed difference. If the closed difference is bigger and exceed the error range, this may because that the cycle slip is wrong. To this situation, we should choose the value that made the closed difference least as the standard.

Adjustment of GPS network

When do adjustment, it have relative observation data (baseline vector) and absolute observation data (the coordination value of the point). The direction datum、measure datum of the net are confirmed by the baseline vector. The position datum lies on the approximation system of the point coordination and adjustment method. According to the proper condition, the adjustment method was classified as lest restriction adjustment and restriction adjustment. Lest restriction adjustment method is a method not roots or roots one point of the net to do adjustment and detect the quality of the GPS network. After adjustment, the direction and measurement are nicety, the precision of position is not nicety. Restriction adjustment is to select the proper point position to root, then give the proper weight and do adjustment. This method may bring effecting to the direction and measurement of the GPS network, thus it need choose appropriate plane coordinate point and bench mark as the restrict point. When select the restrict point, you should control the position and direction of the whole net and distribute them equally. At the condition of control the position and direction should choose the least number of root points and reduce the bad effecting that it brings.

In our field example, selecting two plane points and four elevation points as root points, obtaining the three-dimension coordination by restriction adjustment. The elevation compared to the horizontal elevation combined with three grades leveling, the best difference is 2.2 centimeters, the mean square error of the weakest point is 1.45 centimeters, and the relative mean square error of baseline is 1:94000000 to 1:4000000.

3 The advantages of GPS method and Error analysis

3.1 The advantages of GPS method

It is difficult to keep visible and the structure of control network all well at the same time in the traditional surveying. It needs not to consider visible and built up target by using GPS method. In this method, we can achieve high accuracy of 1×10^{-6} to 2×10^{-6} when the baseline less than 50 kilometers. The time of observation is short, static position method measure a line in 1 to 2 hours, while quick position method only few minutes. GPS provide 3-dimensional coordination, continuous. It can work continually at the perfect place every time.

3.2 Error analysis

There are some reasons to cause the errors between the elevation obtained by level collocation and the real level elevation as follows:

At present, the GPS equipment in our country are Trimble, Hovatol, Tavad, Ashitech, Leica and others. To there precision, the GPS receivers of dual frequency are 5 mm + 1 ppm to 1 mm + 0.1 ppm. GPS receiver precision has a large affection to the results of surveying. It will increase the precision efficiently by enhance the precision of equipments and use the advisable effective.

There will be a large error in the progress to put the physic center of the GPS antenna at its geometric center and aim at the detection point strictly. Nowadays, many GPS equipment have been used the technique of zero physic center of antenna concede with the geometric center. In general, the personal error of aim at the center of antenna and detection point during at 1.5 to 3 millimeters. To a higher level of surveying, this error can be eliminated by force centering equipment and reaches the effect of improve the precision of GPS.

According to connect with the old control network, according to the demand of GPS survey specification about point the choosing, it is very difficult to keep off the disadvantage environment when choose some points. Thus these affected the survey precision. At this condition, we should make the original control point moved to a perfect environment place and use this point as the GPS station.

The elevation of GPS is the ellipsoidal height which is use the ellipsoid as the datum, but the geoids height use the geoids as the datum, the geoids is an irregular surface. There is a deviation between the two references datum and the difference will be change at different area. In the sea area, these two surface coincidences have no difference. In the plain area, the difference is small. In the mountains, the difference changes large. Adopt the force level collocation will bring the difference to the GPS net and effect the precision of each data.

In the data process, do not convert the coordinate but use the geodetic height system directly will avoid the error that is bring by GPS in spirit leveling. At present, some places that used this method have been achieved well effect and quick, simple and economy.

4 Conclusions

In the application of GPS to monitoring land subsidence, the base thing is to resolve questions. Its application cannot be limited because of its errors. Nowadays, the GPS have many difficulties to reach the high leveling precision, it can monitor the area where land subsidence keeps long time and seriously. It is practical to carry out surveying periodical and the efficiency rose obviously with the development of application of GPS and the improvement of software and hardware, the precision of GPS at the aspect of absolute positioning, relative positioning and measure speed. It is sure that this will push the application extensively at the aspect of the observation of geological environment by GPS.

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