Design of Surveying Methodology for Construction Subsidence Monitoring Using GPS Technology

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Key words: GPS technology, construction subsidence, subsidence monitoring, GPS surveying

SUMMARY

Construction subsidence is normally appearance in urban area with the difference level but it is very dangerous for living activity. With the rapid development of GPS technology, nowadays we can use it for many applications as surveying, navigation, land subsidence, etc... Almost applications using GPS technology is tested with a satisfying GPS accuracy. In the world, we have some applications using GPS technology for measuring the movement of construction but the procedure is unclear or not unity. This research projects to several GPS traditional research and using instrument has high accuracy such as Trimble GPS 5700 for designing the best surveying procedure when we want to monitoring the construction subsidence.

Actually, with construction subsidence it will be move follow two direction as horizontal and vertical. But the movement is difference in speed (immediately or slowly and slowly). Currently, in Vietnam, subsidence monitoring is deploying with theodolite instrument and applying GPS technology in this work is a new way. We design surveying job follows a fix frequency (3 months for 1 time) and correlative with Vietnamese seasons. For all surveying times, research will be deployed on the same network control points which are designed follow international standardization. The result of each GPS surveying time will be checked with traditional surveying method with theodolite instrument.

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1. INTRODUCTION

Recently, Vietnam has many large constructions which are built by government, international organization, private company, etc. These constructions are Vietnamese pride and as witnesses to demonstrate with entire of the world that Vietnamese economic is increasing. Construction subsidence is a frequency phenomenon that occurs in recent years. Almost companies control subsidence phenomenon for their construction by traditional method such as total station or theodolite. With the development of science and technology, nowadays, several companies using GPS technology for subsidence monitoring. For each surveying method (traditional or modern way), they have advantage and disadvantage points but in this research, we concentrate to finding a surveying method for GPS instrument and applying it for subsidence monitoring activity. This research also uses a traditional method to validate the results which is extracted by GPS instrument.

2. STUDY AREA

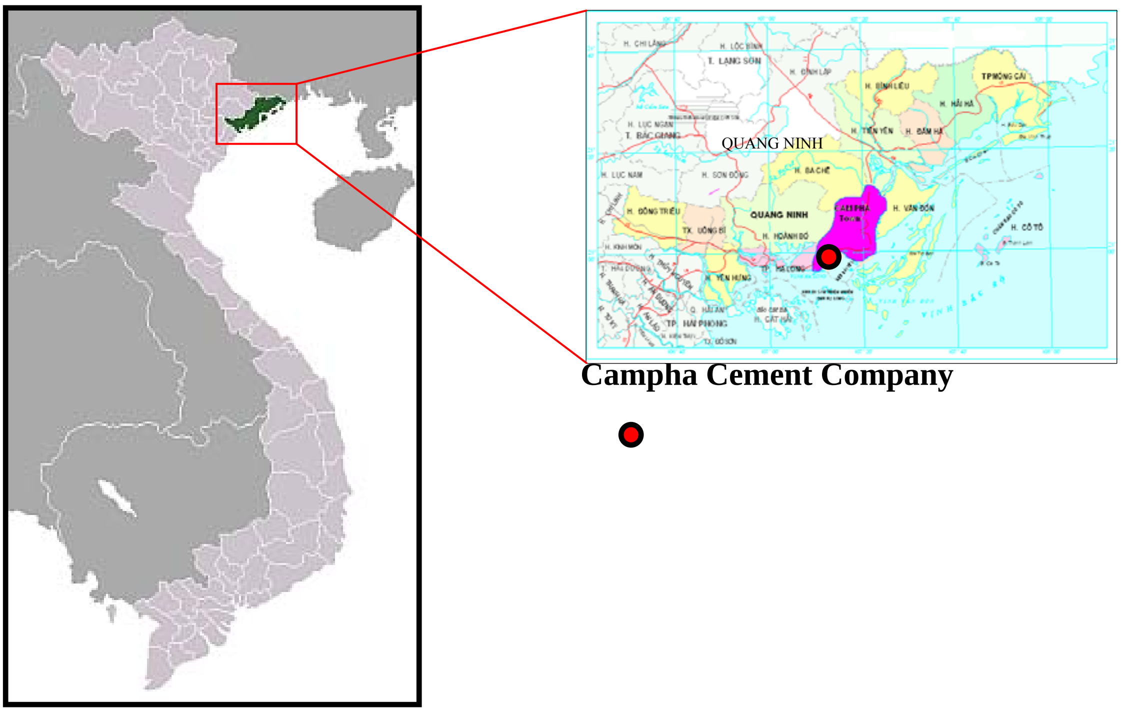

Figure 1: Study area of CamPha Cement Company

QuangNinh is a large province in the North-East of Vietnam and the incomes of province are mainly from industrial and tourist. Campha Cement Company is situated on the reclamation area, along the coast line, with many big constructions. These constructions make a high pressure to foundation. This company has large area (around 70 square ha) and sight direction is clear so this area has advantages for using two surveying method (theodolite and GPS).

3. METHODOLOGY

3.1 Designing and selecting network control points

Base on the documents relate to topography, foundation geology characteristic of the factory and neighboring area, the attribution, press lever, the shake of each unit of the factory. Base on the visibility, the cover lever to calculate and design control point network (Figure 2). Network control includes eight points with five monitoring points such as CD1, CD2, CD3, CD4 and CD5 inside the factory. The monitoring points are the high risk of subsidence. Three standard points RS1, RS2, RS3 built outside the factory and on the rocky mountain which is firm geology foundation. The standard points such as fixed points to monitor the subsidence of the monitoring points. All the points are in the clear area, no limited by subjects and to meet fully the demand of high accuracy GPS measurement

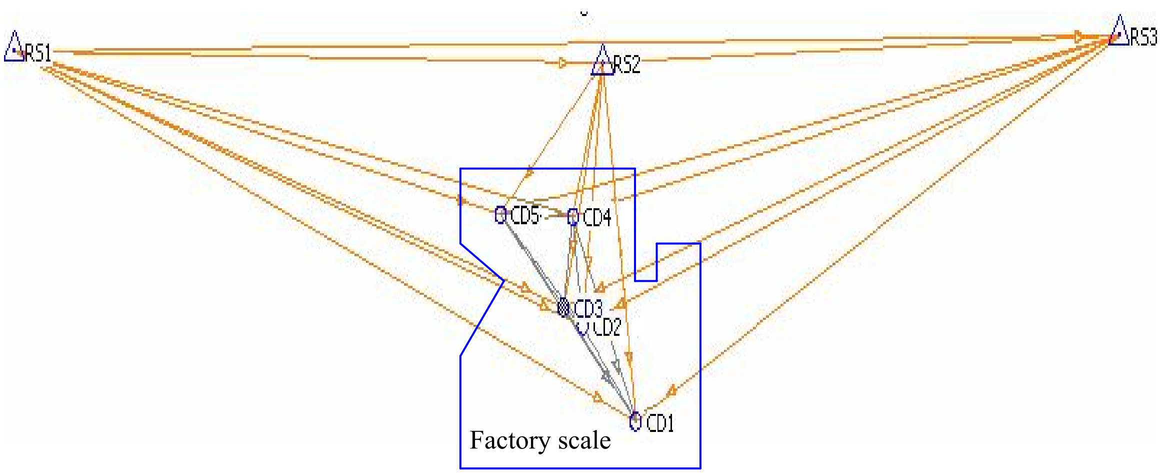

Figure 2: GPS control network to monitoring the subsidence of the factory

3.2 Design survey markers

The survey markers are built to make sure that antennal can not move inside surveying time. The root of the survey marker is concreted and fixed with foundation stone. The connection part between antennal and survey marker is designed to support surveyor plug-in antennal at the same point.

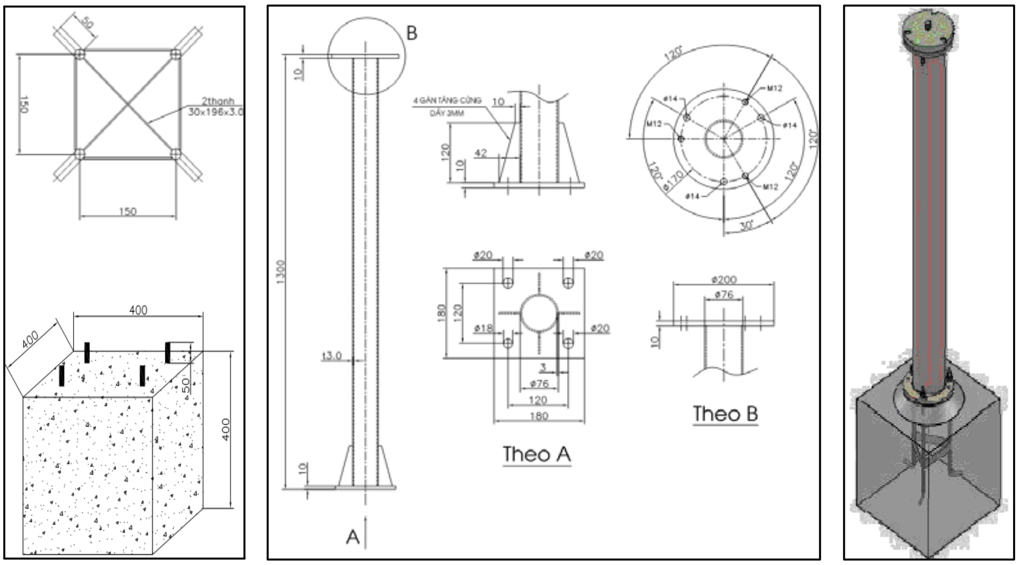

Figure 3: The design of survey marker

3.3 Surveying GPS

Based on the requirement from Ministry of Construsion about ensuring the accuracy in subsidence monitoring. The phase for implementing GPS surveying is designed closely includes selecting GPS instrument, designing network control points, surveying operation and adjustment procedure. Trimble 5700 2 frequencies (L1, L2) with high accuracy is selected to deploy in all of GPS surveying time. For checking the accuracy of instrument, GPS surveying operation is divided into two sub-phased. At the first sub-phased (twelve hours), antennal at eight points are fixed at the center of the survey marker and the next sub-phased (twelve hours) antennal of three monitor points (CD2, CD4, CD5) is moved to another points (test points) far from the center of survey marker about 3 cm. The last, TGO is used to adjust the received data from Trimble 5700.

3.4 Using theodolite surveying for evaluation

Theodolite surveying is a traditional method. It can monitor objects at every situation that depend on accuracy requirement. It is used for checking the GPS surveying data. TC1800 total station with ±2mm distance measurement precision and ±1 second angle measurement precision surveys monitoring control points before GPS surveying deployed. This operation is implemented at four monitoring control points as CD2, CD3, CD4,CD5.

4. RESULTS AND DISCUSSION

4.1 GPS measurement result

The GPS survey data is processed and adjusted by GTO1.63 software to get result.

Table 1: Coordinate of points is surveyed by GPS instrument.
X, Y, Z: Coordinate of measurement points in space coordinate system
N, E, h: Coordinate of measurement points in plate coordinate system (VN2000)

	X	Y	Z	N	E	h
RS1	-1763972.710	5689621.114	2272106.846	2323949.898	497224.634	25.403
RS2	-1767341.226	5688579.069	2272058.068	2323903.024	500750.633	10.873
RS3	-1770284.567	5687620.165	2272155.597	2324009.468	503845.936	6.886
CD1	-1767672.329	5688983.806	2270785.731	2322541.490	500946.822	7.439
CD2	-1767331.594	5688950.523	2271125.998	2322906.758	500631.283	5.309
CD3	-1767211.366	5688963.665	2271190.078	2322974.860	500512.565	6.693
CD4	-1767231.094	5688827.576	2271510.529	2323318.506	500571.763	5.666
CD5	-1766815.891	5688953.519	2271518.857	2323327.302	500137.888	5.964
CD21	-1767331.579	5688950.517	2271126.029	2322906.790	500631.271	5.311
CD41	-1767231.055	5688827.584	2271510.530	2323318.509	500571.723	5.662
CD51	-1766815.886	5688953.510	2271518.891	2323327.336	500137.887	5.967

Table 2: Evaluating the accuracy of the result of GPS measurement bases on test points.
ΔN, ΔE, Δh, D: plate coordinate difference following N, E axes, high difference (Δh) and the distance (D) between test points and monitor points are surveyed by GPS instruments.
Δh(), ΔD(): real high difference (Δh()) and real distance (ΔD()) between test points and monitor points.

	ΔN	ΔE	Δh	D	Δh()	ΔD()
CD2-CD21	0.0327	-0.0123	0.0013	0.0349	0.0000	0.0350
CD4-CD41	0.0030	-0.0393	-0.0033	0.0396	0.0000	0.0400
CD5-CD51	0.0347	-0.0017	0.0033	0.0349	0.0000	0.0350

- The table 2 shows that: GPS survey gives the result very precise (0.1mm with CD5-CD51 and 0.4mm with CD4-CD41) between 2 periods of measurement. There is no coarse error in installation and operation of GPS instrument. It ensures fully the demand of subsidence measurement.
- Assessing the surveyed result following 1h, 2h, 3h, 4h, 6h and 12h period shows that: With the length of period more than 6h, the stableness is good, especially survey 12h period gives us very good result.
- The accuracy and stableness of height component is less than plate coordinate. When we moved the antennae to test points, the height component is changed a lot.

- At very clear positions and good visibility, the quality of surveyed result is better, especially height component.

4.2 Total station survey result

The survey data is adjusted in a pseudo plate coordinate system with 2.5 seconds angle survey error, 1mm distance survey error and 1.5539 RMS error. To compare the accuracy of the result of GPS measurement and the result of Total station measurement, we have to move the coordinate of points, which receipts from 2 methods to the same coordinate system, VN2000.

Table 3: The result of Total station and GPS measurement

Y_{TS}, X_{TS}: Coordinate of points is measured by Total station method in pseudo plate coordinate system.
N_{TS}, E_{TS}: Coordinate of points is measured by Total station method in the VN2000 coordinate system
N_{GPS}, E_{GPS}: Coordinate of points is measured by GPS method in the VN2000 coordinate system**.**

	Y_{TS}	X_{TS}	N_{TS}	E_{TS}	N_{GPS}	E_{GPS}
CD5	10000.0000	10000.0000	2323327.3017	500137.8883	2323327.3017	500137.8883
CD2	10000.0000	10648.3017	2322906.7581	500631.2829	2322906.7577	500631.2833
CD4	10274.7481	10335.9153	2323318.5043	500571.7640	2323318.5063	500571.7627
CD3	9974.8180	10513.7748	2322974.8586	500512.5651	2322974.8597	500512.5653

Table 4: Comparing the coordinate difference between Total Station measurement and GPS measurement

ΔN, ΔE: the coordinate difference of points between Total Station measurement and GPS measurement
ΔD: the distance difference of points between Total Station measurement and GPS measurement

	ΔN	ΔE	ΔD
CD5	0.0000	0.0000	0.0000
CD2	0.0004	-0.0005	0.0006
CD4	-0.0020	0.0013	0.0024
CD3	-0.0010	-0.0003	0.0011

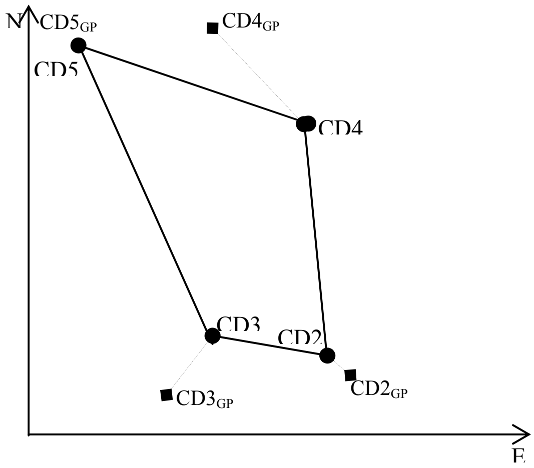

Figure 4: The figure of measured points by GPS method ($CD2_{GP}$, $CD3_{GP}$, $CD4_{GP}$, $CD5_{GP}$) and Total station method (CD2, CD3, CD4, CD5).

- The coordinate difference of points (table 4) obtained by Total station and GPS method is not worth considering. The highest of distance difference is 2.4mm at CD4 point (the others is smaller than 1.1mm).

- The figure 4 shows that: The direction difference of survey points obtained by 2 methods is distributed randomly, not following any the rule of error. Thus, there is not system error in measurement.
- The figure of control point network built on GPS measurement and Total station measurement is almost undifferentiated.

5. CONCLUSION

Using GPS for subsidence monitoring is new step to support companies monitoring their constructions by themselves but the surveying procedure is not unification. Actually, almost companies monitor the subsidence construction by traditional surveying such as theodolite because it is accepted by law. As we know, GPS surveying still has many advantage especially difficult terrain or long based line. With the study area, Campha Cement Company stays in mountain area and along with coastal line so it is very difficult to navigating based line from the standard control to monitor points inside company. In this case, GPS surveying is very useful. The results from GPS surveying inside company are checked by theodolite surveying. The results which are got from two method is not too much different after adjustment and applying GPS for subsidence monitoring is acceptable. This method will be repeated in the future to improve reliability on GPS for construction subsidence monitoring.

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