Study of 2G Technique and Method for Landslide Monitoring

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Main Contents

1 Background

1) Characteristics of landslide hazard:

—— Conditional-terribleness

—— Phyletic-variety

—— Spatial-randomicity

—— Temporal-paroxysmic

—— Sequential-ponderance

2) Requirements of monitoring technique and methods:

—— Rapidity

—— Flexibility

—— Veracity

—— Integration

3) What is 2G technique and method?

Corresponding to 3S, 2G technique and method is the combination and integration of GPS and Georobot.

There are some applications of landslide monitoring with GPS or Georobot solely, while few with 2G technique and method.

The 2G technique and method has the advantages of GPS and Georobot.

2 Research results

—— Research on optimization design of landslide monitoring network

—— The software of landslide deformation automatic monitoring and data processing with Georobot (called as Georobot_Net) is developed

—— The software system of landslide deformation automatic monitoring using Georobot (called as Geo_DAMOS) is developed

3 Theory of the landslide monitoring network layout

1) Layout of landslide monitoring network

—— Terrestrial network

* the average side of network is less than 1500 m

—— GPS network

* large landslide; good headspace condition;
the average side of network is over 1500 m

—— Combination network of GPS and high precise distance measurements with EDM

* large landslide; good headspace condition;
the average side of network is over 1500 m;
GPS as main; terrestrial side as auxiliary

2) Theory of precision matching between side and angle

It's pointed that side measurement is relevant to lengthways error, while angle measurement is relevant to transverse one, both are nearly relevant to side.

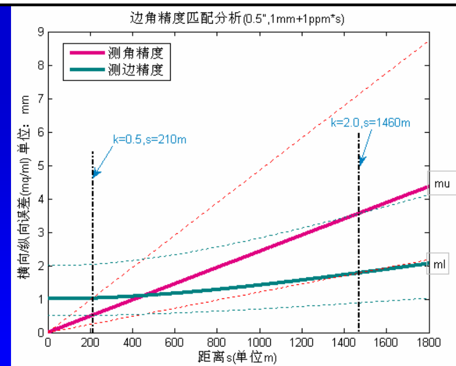
It's basically matched when matching value (denoted *K*) change the range from 0.5 to 2.

For Leica TCA2003

—nominal angle accuracy of 0.5"

—nominal distance accuracy of $1mm + 1ppm \cdot S$

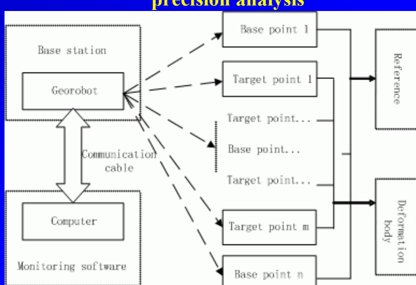
Value of *K*	0.5	1	2
Distance(m)	210	450	1460



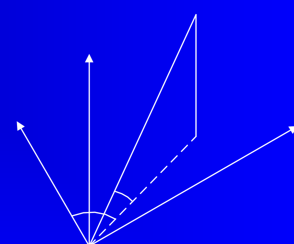
The analysis results of theory of matching between side and angle

4 Georobot technique and method

1□ The polar coordinate measurement method and its precision analysis



Frame of the Deformation Monitoring System Based on Georobot



Sketch Map of Polar Coordinate Measurement System

Inclined distance (m)	the MSE of point P (mm)	the plane MSE of point P (mm)	the elevation MSE of point P (mm)			
			$\alpha=0°$	$\alpha=10°$	$\alpha=20°$	$\alpha=30°$
100	1.1	1.0	0.2	0.3	0.4	0.6
…	…	…	…	…	…	…
500	2.0	1.6	1.2	1.2	1.3	1.3
…	…	…	…	…	…	…
1000	3.6	2.7	2.4	2.4	2.5	2.5
…	…	…	…	…	…	…
1500	5.3	3.9	3.6	3.6	3.7	3.7
…	…	…	…	…	…	…
2000	7.0	5.1	4.8	4.9	4.9	5.0

Precision analysis results of polar coordinate measurement with Leica TCA2003 Georobot

2□Differential correction

—— **Differential correction of horizontal angle**

$$\delta = \frac{\sum_{i=1}^{n}(Hz_{ij} - Hz_{ik})}{n}$$

j=1,2,L ,m k=1,2,L ,m

m — the times of measuring

n — the count of base points

$$Hz_P = Hz'_P + \delta$$

δ — the correction value of horizontal angles

Hz_{ij} — the horizontal angles of base points in measuring cycle j

Hz_{ik} — the horizontal angles of base points in measuring cycle k

—— Differential correction of inclined distance

$$\Delta d = \frac{\sum_{i=1}^{n} \frac{d_{i1} - d_{ik}}{d_{ik}}}{n} \qquad k=1,2,\cdots,m$$

$$d_p = (1 + \Delta d) d'_p$$

m — the times of measuring

n — the count of base points

Δd — proportional coefficient of meteorological correction

d_{i1} — the inclined distance of base points in the first measuring cycle

d_{ik} — the inclined distance of base points in the first measuring cycle k

—— Differential correction of elevation difference

$$\begin{cases} c_i = \dfrac{h_{i1} - h_{ik}}{(d_{ik} \cdot \cos\alpha_{i1})^2} \\ c = \dfrac{\sum_{i=1}^{n} c_i}{n} \end{cases}$$

$$h_{pk} = d_{pk} \cdot \sin\alpha_{pk} + c \cdot (d_{pk} \cdot \cos\alpha_{pk})^2$$

$$D_p = \sqrt{d_P^2 + h_P^2}$$

3□Method of interpolated meteorological correction

—— Selecting several representative monitoring points and base points (located in the margin or center of measuring area)

—— Writing temperature and air pressure when measured

—— Calculating meteorological proportional coefficient with following formula

$$\Delta D = 285.92 - \left(\frac{0.29065 \times P}{1 + \alpha \times t} - \frac{4.126 \times 10^{-4} \times h}{1 + \alpha \times t} \times 10^{x}\right)$$

—— Calculating final inclined distance with following formula

$$D' = (1 + \Delta D) D$$

5 Landslide monitoring mode

Two kinds of Landslide monitoring mode :

—— mobile cycle monitoring□

—— fixed continuous remote controlling monitoring.

1□ Mobile cycle monitoring

- Fixing Georobot onto the observation stand of the station
- Putting the prisms onto the monitoring point
- Doing station settings
- First observation of monitoring points and base points
- Georobot Automatic measuring and automatic checking limit difference
- Moving measuring station
- Finishing outer measuring work
- Indoor data processing

2) Fixed continuous remote controlling monitoring

—— Suitability

rapid sliding velocity; important; conditioned landslides

—— Requirements

remote controlling; data communication;

building observation house

—— Advantages

non-attended continuous real-time observation;

—— Disadvantages

cost too much; need care and protect; difficult for ordinary landslide

Testing of fixed continuous remote controlling monitoring (1)

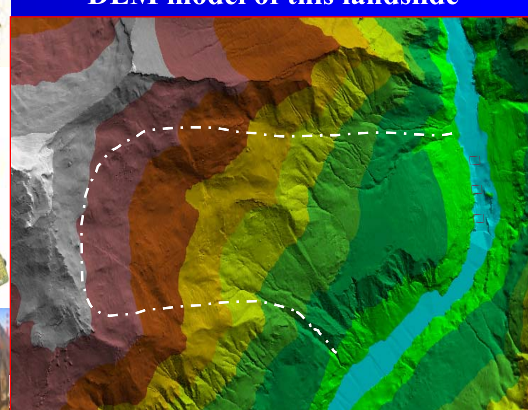
Testing of fixed continuous remote controlling monitoring (2)

Testing of fixed continuous remote controlling monitoring (3)

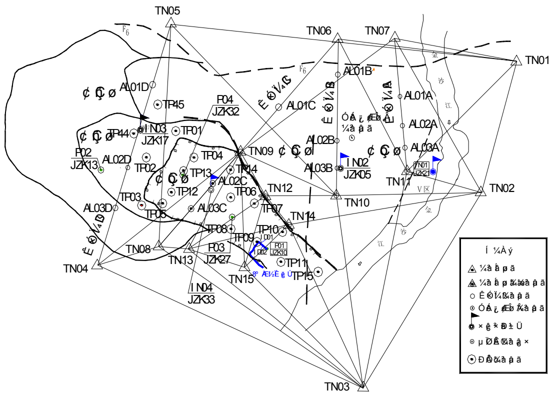
6 Testing and beneficial result analysis

Selecting certain a landslide in Yunnan, China, for testing and practical application. This landslide monitoring network is composed of 15 monitoring points. While the deformation monitoring network of this landslide body (district □) has 19 points, they are 6 monitoring network points, 2 collimating line points and 11 pass points.

DEM model of this landslide



Layout figure of this landslide monitoring system



Landslide Area Monitoring Georobot Station

Landslide deformation monitoring locale

The analysis results of comparison of landslide monitoring network

	General monitoring	Georobot monitoring
Monitoring equipment & Software	4 T3 theodolites 4 EDM equipments	1 Georobt (Leica TCA 2003) 6-8 prisms Georobot_Net
Personnel collocation	4 technicians 5-8 workers	1-2 technicians 8-10 workers
Outer observation time	about 25 days	about 7-10 days
Inner processing time	5 days	2 days

The analysis results of comparison of landslide body deformation monitoring

	General monitoring	Georobot monitoring
Monitoring equipment & Software	4 T3 theodolites 4 EDM equipments	1 Georobt (Leica TCA 2003) 6-8 prisms Geo_DAMOS
Personnel collocation	4 technicians 5-8 workers	1-2 technicians 8-10 workers
Outer observation time	about 8-10 days	about 2-3 hours
Inner processing time	3 days	half a day

7 Conclusions

From the above discussion, experimentation and practical application, we can find that 2G technique and method for landslide deformation monitoring is automatic highly, precise (up to millimeter-level), reliable, flexible, economical and easy taking. And it has also instructional significance and application perspective for the deformation monitoring of other projects.


Thank you!