ENVIRONMENTAL AND EARTH SCIENCES RESEARCH JOURNAL
Vol.2, No.4, 2015, pp.11-16
http://dx.doi.org/10.18280/eesrj.020403

STUDY ON STATISTICAL CHARACTERISTICS OF DEEP DISPLACEMENT OF MONITORING DATA FOR SOIL SLOPE

Haidong Jiang

Department of Geological Engineering, School of Geosciences and Info-Physics, Central South University
Changsha, Hunan province, China

Email: 59366197@qq. com

ABSTRACT

To research on statistics features of monitoring data of deep displacement for soil slop, analyzed statistical digitals and attributes feature by OriginLab OriginPro 8. 5 software. Through statistical analysis of statistical digitals and attributes feature on different depths under different conditions, showed that its characteristics appeared leaping mutations in 13-16 m, and determined potential sliding surfaces between 13-16 m.

Keywords: Deep displacement of soil, Monitoring data, Statistic characteristics, Sliding surface.

1. INTRODUCTION

Deep displacement monitoring was a dynamic monitoring of the accurately measuring horizontal displacement at different depth, and determined the range of sliding surface [1-2]. Deep horizontal displacement of soil slop included e inclinometer and TDR (TDR, Time Domain Reflectometry).

Inclinometer was a more effective monitoring method of underground horizontal displacement currently, and used most widely. It was piecemeal measure to get the changes of the horizontal displacement from bore, so that its size, direction and depth of deformation could be more accurately determined. TDR was a remote measurement technology applied to spatial location and measurement of morphological characteristics of objects. Nearly 10 years, it was one of the hot spot, and geotechnical engineering more public concern on underground displacement monitoring by TDR because of its secure, convenient, fast, automatic, remote monitoring. Because its optical spectrum analyzer was expensive and the harsh working conditions requirements was extremely complex, so that it was very few practical applications. So it needed further research, development and application. Although more analysis and research on surface deformation, but analysis and research on the monitoring data of deep development was gravely inadequate [3-6]. By analysis of monitoring data of soil displacement body was prerequisites of predictive analysis and mathematical modeling.

2. LABORATORY CALIBRATION OF INCLINOMETER

2.1 Laboratory verification process

Check must be made in the laboratory first before service entry, and the process was as follows:

(1) calibration leveling: according to the two perpendicular glass level bubbles to level.

(2) inclinometer probe was clamped on the calibration stage, the direction of x-direction of probe paralleled to slot of calibration holder, and tried to keep the probe vertically.

(3) inclinometer connected to the host, and set the parameters: deep was 15 meters, and distance of measuring point was 1 m, besides set the bottom hole as the benchmark.

(4) validated angles changed from 0~15° and with 1 degree spacing, measured data was positive direction; validated angles changed from 0~-15° and with 1 degree spacing, measured data was reverse direction. Recorded the changes of each data value.

(5) in order to obtain averages, measured 3 times in a row.

2.2 Check data processing

The process of inclinometer calibration data was as follows:

(1) Imported the raw data, and saved it as a table.

(2) There were two main methods to determine whether the error instrument met the requirements.

(3) The method of numerical difference comparison was that the previous data minus x direction data, and the value between 8.2~9.2 was normal.

(4) The method of calculate angle was compared calculate angles with calibration data.

(5) The value of X was calculated accordance to the equation (1). X_0 was the measurement value of the bottom point.

$$X = X_P - X_R \tag{1}$$

(6) The calculation values of the horizontal displacement was as follow,

$x_i = X - X_0$ (2)

(7) Angle measurement in degrees was as follow,

$$\theta = a\sin(x_i / l) * 180 / \pi \quad (3)$$

The calibration results was shown in table 1:

Table 1. Result of instrument calibration

angle	x_P-x_R		x-x0		angle conversion		Average	Error
	reverse	positive	reverse	positive	asin(x/l)*180/3.14			
29	-1.78	-1.66	497.66	499.48	29.9	30.0	29.9	0.9
28	18.01	18.03	477.87	479.79	28.6	28.7	28.6	0.6
27	34.28	31.62	461.60	466.20	27.5	27.8	27.7	0.7
26	42.84	56.28	453.04	441.54	27.0	26.2	26.6	0.6
25	60.13	72.49	435.75	425.33	25.8	25.2	25.5	0.5
24	82.89	89.99	412.99	407.83	24.4	24.1	24.2	0.2
23	102.66	105.84	393.22	391.98	23.2	23.1	23.1	0.1
22	120.98	125.94	374.90	371.88	22.0	21.8	21.9	0.1
21	136.82	141.8	359.06	356.02	21.1	20.9	21.0	0.0
20	148.97	156.31	346.91	341.51	20.3	20.0	20.1	0.1
19	168.84	175.46	327.04	322.36	19.1	18.8	19.0	0.0
18	185.75	195.6	310.13	302.22	18.1	17.6	17.8	0.2
17	211.8	212.86	284.08	284.96	16.5	16.6	16.5	0.5
16	229.12	230	266.76	267.82	15.5	15.5	15.5	0.5
15	247.6	246.05	248.28	251.77	14.4	14.6	14.5	0.5
14	266.71	265.05	229.17	232.77	13.3	13.5	13.4	0.6
13	283.5	284.63	212.38	213.19	12.3	12.3	12.3	0.7
12	297.54	297.93	198.34	199.89	11.4	11.5	11.5	0.5
11	317.46	316	178.42	181.82	10.3	10.5	10.4	0.6
10	331.24	331.25	164.64	166.57	9.5	9.6	9.5	0.5
9	350.11	349.99	145.77	147.83	8.4	8.5	8.4	0.6
8	368.47	368.16	127.41	129.66	7.3	7.5	7.4	0.6
7	385.44	379.61	110.44	118.21	6.3	6.8	6.6	0.4
6	399.86	399.9	96.02	97.92	5.5	5.6	5.6	0.4
5	418.14	416.89	77.74	80.93	4.5	4.6	4.6	0.4
4	434.74	433.4	61.14	64.42	3.5	3.7	3.6	0.4
3	451.98	449.83	43.90	47.99	2.5	2.8	2.6	0.4
2	467.43	465.88	28.45	31.94	1.6	1.8	1.7	0.3
1	479.33	486.53	16.55	11.29	0.9	0.6	0.8	0.2
0	495.88	497.82	0.00	0.00	0.0	0.0	0.0	0.0

According to the table 3-1, the error of instrument angle was 0.0-0.9°, and that met the requirements of measurement error.

3. STATISTICS FEATURES OF MONITORING DATA AND ANALYSIS

Rock-soil mass is an open, dynamic and complex systems. Monitoring of geotechnical engineering is an extremely important work to ensure safety and rational design. Statistical characteristics of random processes soil displacement field was the basis of data analysis and Predictive Modeling. Took Mulian Road slope in Changsha city for example, figure 1 was the monitoring plan.

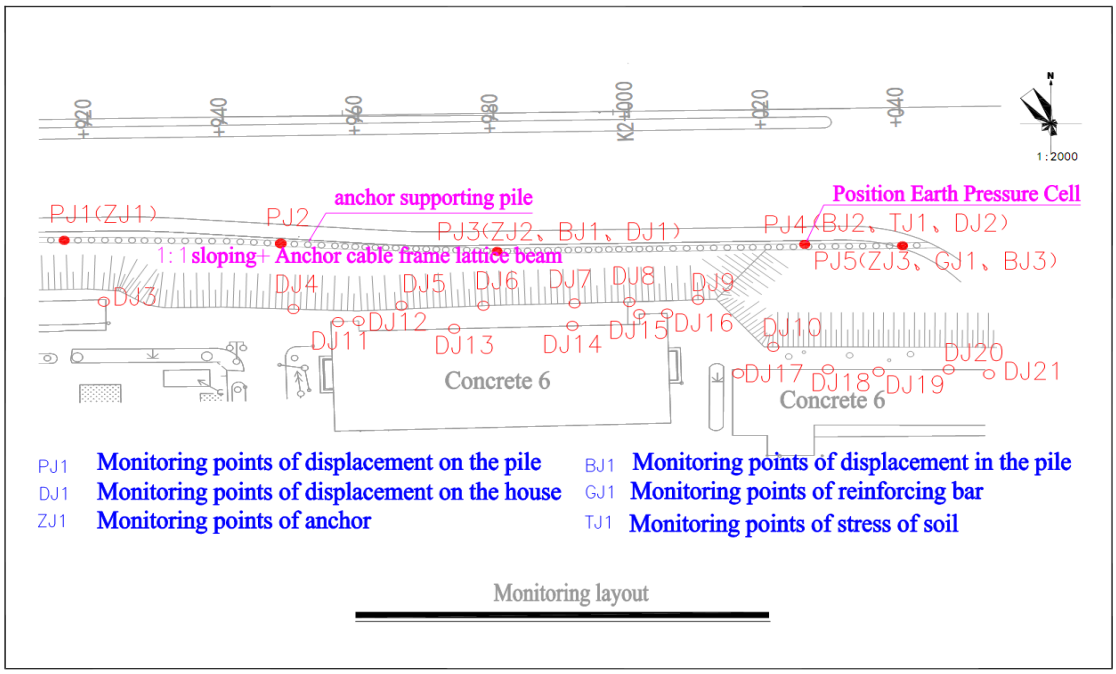

Figure 1. Monitor layout

3.1 Statistical characteristics of the soil at different depth

Monitoring data of inclinometer got from"2011/12/7" to"2013/4/7", and drew the trend chart as figure 2. Statistical characteristics of deep displacement data for various depth was as follow table 2:

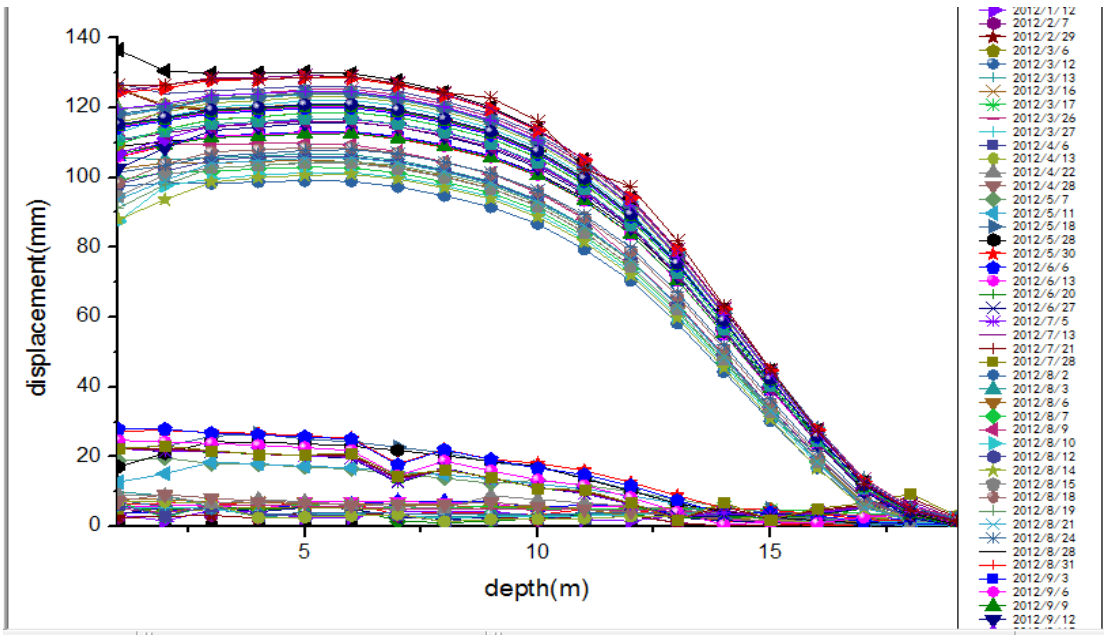

Figure 2. Deep displacement - time trend chart

Table 2. Statistics features of deep soil displacement monitoring data

Deep (m)	mathematical expectation (mm)	Max (mm)	min (mm)	standard deviation	correlation coefficient
1	69.60	2.49215	136.54	49.60	0.71
2	70.97	1.57613	130.47	50.66	0.71
3	72.35	3.22135	129.85	51.54	0.71
4	72.39	2.35281	129.92	52.24	0.72
5	72.83	2.43629	130.15	52.57	0.72
6	72.73	2.52508	129.72	52.72	0.72
7	70.79	1.57703	127.74	53.03	0.75
8	69.52	1.10941	124.46	51.47	0.74

Deep (m)	mathematical expectation (mm)	Max (mm)	min (mm)	standard deviation	correlation coefficient
9	67.21	1.51778	122.81	50.09	0.75
10	63.53	1.69805	116.16	47.91	0.75
11	58.75	1.86543	105.11	44.24	0.75
12	52.39	1.60904	97.31	39.95	0.76
13	43.56	1.02364	81.89	34.07	0.78
14	34.08	0.17644	63.23	26.47	0.78
15	24.31	0.3883	45.04	18.72	0.77
16	15.03	0.26655	28.19	11.05	0.74
17	7.06	0.3454	13.69	4.58	0.65
18	3.17	0.17755	9.31	1.89	0.60

From table 2 and figure 3, it showed the value of statistical characteristics increased with the depth at the same place, but standard deviation decreased from 1m to 19m. Besides, displacement trend significantly increased from 19m to1m.

3.2 Statistical characteristics of soils under different conditions

As the construction progressed, statistical characteristics of deep displacement could reflect the situation of the construction which changed with time.

Table 3. Statistics features changed with time

Time	Mean	Standard Deviation	Min	Max
"2011/12/7"	3.71	2.43	0.27	6.76
"2011/12/9"	4.65	1.92	0.56	7.30
"2011/12/10"	4.35	2.50	0.29	7.10
"2011/12/13"	3.16	1.56	1.11	5.73
"2011/12/28"	2.81	1.85	0.18	5.54
"2012/1/12"	3.00	1.00	1.58	4.70
"2012/2/7"	2.12	1.32	0.18	4.04
"2012/2/29"	2.08	1.30	0.18	4.01
"2012/3/6"	4.59	1.34	1.19	5.68
"2012/3/12"	3.43	1.62	0.38	7.49
"2012/3/13"	3.60	2.30	0.74	9.88
"2012/3/16"	4.47	2.49	0.68	8.06
"2012/3/17"	4.90	1.24	2.54	7.10
"2012/3/26"	4.56	1.08	2.23	6.31
"2012/3/27"	3.19	1.26	0.52	5.54
"2012/4/6"	2.75	1.40	0.82	6.15
"2012/4/13"	3.19	1.80	1.18	7.22
"2012/4/22"	5.45	2.62	0.88	9.16
"2012/4/28"	4.68	2.82	0.52	9.04
"2012/5/7"	10.87	6.63	0.66	19.63
"2012/5/11"	10.03	6.60	0.19	18.41
"2012/5/18"	14.17	9.94	0.35	26.59
"2012/5/28"	13.33	9.19	0.71	24.25
"2012/5/30"	15.40	10.04	1.02	27.58
"2012/6/6"	14.86	10.40	0.61	27.91
"2012/6/13"	12.44	9.43	0.07	24.72
"2012/6/20"	11.48	7.85	0.47	22.36
"2012/6/27"	11.63	7.67	1.01	22.34
"2012/7/5"	11.76	7.60	1.55	22.33
"2012/7/13"	11.95	7.54	2.09	22.31
"2012/7/21"	12.20	7.48	2.10	22.36
"2012/7/28"	12.49	7.43	1.99	23.04
"2012/8/2"	66.82	37.67	1.32	99.07
"2012/8/3"	72.43	40.11	1.32	106.65
"2012/8/6"	70.96	39.55	1.38	104.82
"2012/8/7"	69.63	38.84	1.31	102.90
"2012/8/9"	74.13	41.30	2.10	109.73
"2012/8/10"	67.88	37.97	0.86	101.39
"2012/8/12"	71.60	39.57	1.71	106.07
"2012/8/14"	67.24	37.49	2.85	100.85
"2012/8/15"	69.97	39.14	1.14	104.10
"2012/8/18"	73.42	40.33	1.65	108.46
"2012/8/19"	70.21	38.88	1.50	104.57
"2012/8/21"	70.80	39.47	1.63	105.69
"2012/8/24"	73.72	40.07	1.23	108.00
"2012/8/28"	78.30	41.34	1.44	113.02
"2012/8/31"	77.44	41.38	1.53	112.65

Time	Mean	Standard Deviation	Min	Max
"2012/9/3"	77.64	41.88	0.50	113.14
"2012/9/6"	77.47	41.64	0.82	112.82
"2012/9/9"	77.44	41.60	0.54	112.62
"2012/9/12"	78.54	42.59	0.03	115.85
"2012/9/15"	79.77	42.71	1.82	116.71
"2012/9/18"	79.61	42.94	1.34	116.08
"2012/9/21"	83.77	44.93	1.98	125.30
"2012/9/24"	81.29	43.38	2.63	118.74
"2012/9/26"	86.16	45.20	2.33	125.31
"2012/10/8"	80.26	43.00	1.92	116.87
"2012/10/12"	83.75	45.09	1.51	125.36
"2012/10/15"	81.25	43.50	1.72	118.70
"2012/10/19"	86.18	45.15	2.76	125.33
"2012/10/23"	83.56	44.63	2.11	122.17
"2012/10/28"	87.57	46.42	2.26	126.97
"2012/11/2"	84.68	44.95	2.14	123.17
"2012/11/8"	85.52	45.32	2.12	124.26
"2012/11/13"	85.36	45.34	2.10	123.98
"2012/11/16"	85.74	45.50	2.11	124.34
"2012/11/22"	85.30	45.25	2.17	123.90
"2012/11/28"	85.48	45.33	2.22	124.11
"2012/12/2"	89.61	48.76	0.38	136.55
"2012/12/7"	88.31	47.29	1.60	128.73
"2012/12/12"	82.39	44.05	1.49	119.85
"2012/12/20"	82.71	44.20	1.51	120.29
"2012/12/27"	82.87	44.30	1.51	120.55
"2013/1/18"	83.14	44.42	1.58	120.93
"2013/2/27"	85.70	45.84	1.56	124.75
"2013/3/16"	88.61	47.43	1.85	129.24
"2013/4/7"	89.06	47.71	1.52	128.99

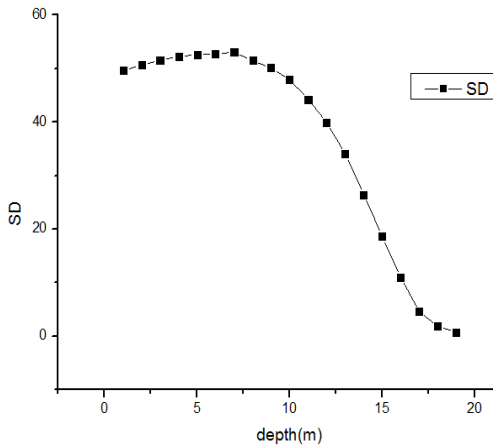

Figure 3. SD - Depth trend chart

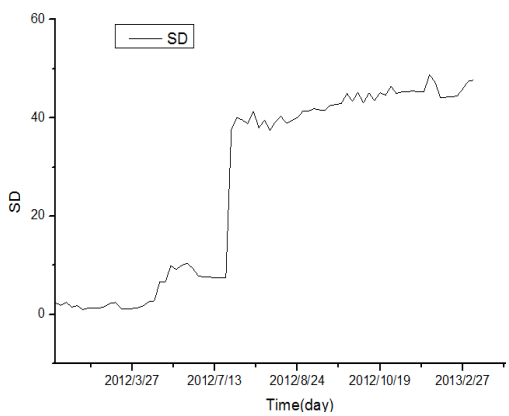

Figure 4. Deep displacement - time trend chart

From table 3 and figure 4, it showed the value of statistical characteristics increased with time at the same place. Besides, the value of statistical characteristics jumped at "2012/8/2" and it indicated risk of landslip.

4. CONCLUSIONS

By analyzing the value of statistical characteristics for the displacement of soil, not only speculated sliding surfaces buried deep between the 13 m and16 m, but also the value of statistical characteristics jumped at "2012/8/2" and it indicated risk of landslip. Besides, it was the prerequisite ofpredictive analytics and mathematical modeling.

REFERENCES

1. LIN M.L., WANG K.L., "Seismic slope behavior in a large-scale shaking table model test," *Engineering Geology*, 86(2-3): 118-133, 2006.
2. HARRIS C., SMITH J.S., MICHAEL C.R.D., etc., "An investigation of periglacial slope stability in relations to soil properties based on physical modeling in the geotechnical centrifuge," *Geomorphology*, 93(3-4): 437-459, 2008.
3. Wen Hongyan, Zhang Zhenglu, "Detection of the periodical signal in the deformation analysis," *Wuhan IAG Workshop on Monitoring of Constructions and Local Geodnamic Process*, (5): 22-24. 36-44, 2001.
4. Zhang Zheng Lu, Huang Quan Yi, Chenmilina Klaus, "Research on geological landslide problems related on the Three Gorges Project," *Wuhan IAG Workshop on Monitoring of Constructions and Local Geodnamic Process*, (5): 22-24, 36-44, 2011.

5. Chen Z.Y., "Random trials used in determing global minimum factors of safety of slopes," *Candian Geotechnical Journal*, 40: 675-683, 2003.

6. Wolf A., "Determing Lyapunov exponents from a time series," *Physica 16D*, 285. 1988.