ISSN 0974-5904, Volume 10, No. 03

DOI:10.21276/ijee.2017.10.0307

www.cafetinnova.org

International Journal of Earth Sciences and Engineering

June 2017, P.P. 513-517

Strength Characteristics of Loess under Large Shear Displacement

FURONG YAN, NA HE AND XUEYUAN HU

School of Civil Engineering, Henan Polytechnic University, Jiaozuo, Henan 454003, CHINA

Email: *123423710@qq.com, hn61886@163.com, 253366377@qq.com*

Abstract: *To study the strength characteristics of loess under large shear displacement, the repeated shear test was conducted in the laboratory. To better understand the corresponding mechanism of strength variation, three or four samples with different moisture content was prepared, and different vertical pressure was applied; with the help of the experiment equipments, peak strength and residual strength was obtained simultaneously. By analyzing the results of the shear experiments, we found that the peak strength and residual value is little higher under natural moisture content, and along with saturation degree increased, c value decreased rapidly while the internal friction angle (φ) varied a little. Therefore the following conclusions can be concluded: viscous resistance of soil decreased sharply mainly due to moisture content increased, which in turn resulted in decreasing of internal friction forces. Moreover, after the undisturbed soil samples fully saturated, the bridge connection becomes weaken, and soluble salts dissolve gradually, because of these the structural strength decreased sharply. For identical soils, the residual strength is less than its peak strength.*

Key words: *Loess, Shear displacement, Landslide, Residual strength, Repeated shear test*

1. Introduction

The Loess Plateau in China is well-known for suffering from among the highest levels of water shortage and soil erosion in the world (Yang et al. 2015). China is the country with most widely distributed loess area in the world, and its loess area accounts of 6.63% of total nation land area. The landslide disaster occurs frequently for complex natural condition and becomes major factors hindering the social and economic development of loess regions (Dekai 1998, Jin-xing et al. 2002, Xu et al. 2007). According to statistics, one third of landslide disasters occurred in loess area. From 1949 to 1990, at least 1025 people directly died from landslide disasters merely in the part area of the three provinces of Shaanxi, Gansu, and Qinhai. On August 8, 1955, loess landslide occurred at Wolong Temple in Xibao Section of Longhai Railway Line damaged 230m roadbed and suspended the transportation for several days. On March 7, 1983, loess landslide of Sale Mountain in Dongxiang County, Gansu Province in a moment resulted in three counties to be covered, 1000-m roads, over 29hm 2 farmland, and two reservoirs destroyed. On August 11, 1990, loess landslide occurred at lathe factory, Tianshui City, ruined six workshops and killed seven people. In addition, many famous large disasters such as Bailu Plateau Form Landslide, Haiyuan Earthquake Landslide, and Jiangliu Landslide happened in loess regions. Landslide caused tremendous economic losses to human beings due to its extensive distribution and high frequency. In 1995, landslides happened over 3000 times and resulted in at least 776 people died and direct economic loss of 23.52 hundred million yuan. In the 1990s, extremely active loess landslide threatened people's life. It is urgent that loess landslide mechanism, forecast, and disaster reduction measure should be studied so as to promote sustainable development of ecological environment in loess area (Fu 1989, Dongtao 1995, Zhang et al. 2006). Loess landslides occurring in China lead to a huge economic losses every year (Wang 2004, Liao et al. 2008, Ji et al. 2009, Bai et al. 2011, Li et al. 2013).

For the rational evaluations concerning mitigation and prevention of landslides, it is important to understand the shear strength properties of landslide soil being directly related to stability analysis of landslides (Hamel 2004, Kimura et al. 2011). Due to the special properties of loess that including macro-pore structure characteristics and structure sensitivity to water, which promoting loess plays an important role in engineering practice in loess regions. The mechanical properties of Loess soil greatly influenced by water, and the slope stability were mainly determined by mechanical properties of Loess soil (Derbyshire et al. 1994, Xiangyi 1995, Zhang et al. 2009).

To better understand the mechanism of Loess landslides, the shear strength that including peak strength and residual strength should be studied meticulously (Zhang et al. 2012). The main objective of this research is to obtain the stress-strain relationships under different conditions, and analyzing the variation laws of peak strength and residual strength, which can be facilitated to analyze landslides formation process, and would be beneficial to landslide disaster prevention and mitigation (Cruden et al. 1996, Wei-sheng et al. 2007, Liao and Su Lj 2008, Xu et al. 2008, Tu et al. 2009, Wang et al. 2014).

Received: January 03, 2017; Accepted: May 16, 2017; Published: June 30, 2017

International Journal of Earth Sciences and Engineering, 10(03), 513-517, 2017, DOI:10.21276/ijee.2017.10.0307

2. Methods

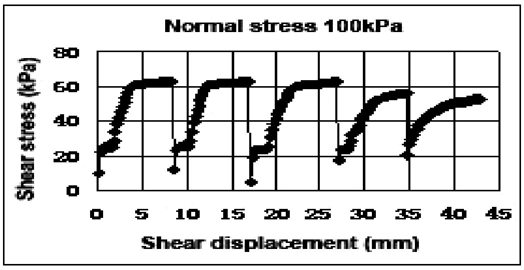
In order to study the shear strength characteristics under large displacements, Yan'an typical loess samples were selected and prepared, and then repeated shear tests were carried out in the laboratory, 3 or 4 samples were repeatedly sheared under different vertical pressure, while the displacement reaches its peak value, the final stable shear stress was calculated, and the residual strength can be determined. To better understand the corresponding mechanism, ZJ type Four-linking strain-control direct shear apparatus were employed in this research. The repeated shear tests were conducted with shear rates 0.06mm/min. After the sliding surface presented under different vertical pressure, the samples were under 4 or 5 times repeat shear test again, with each shear displacement around 8 to 10mm, and the total displacement reaches about 30 to 40mm, and the time interval between the repeat shear tests is about half an hour.

Considering the influence of moisture content, the undisturbed and fully saturated Q_3 and Q_2 Loess (a total of 16 samples) under different vertical pressures were sheared, respectively. And then the peak strength and residual strength can be acquired, respectively.

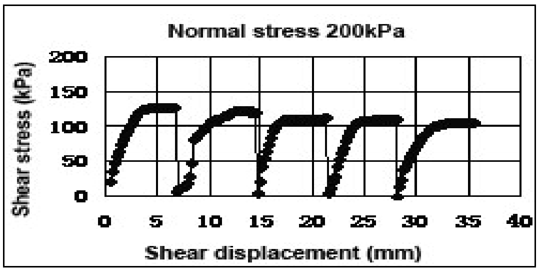
3. Test results

3.1 Shear stress and shear displacement relationship curves

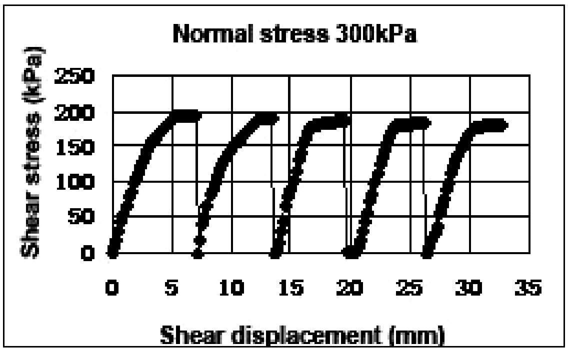
By analyzing the experimental results we obtained the stress-strain displacement relationship curves of two different types of loess (Q_3 and Q_2) under different conditions (natural and fully saturated), as shown in Fig.1, Fig.2 and Fig.3.



(a). The stress-strain curves under vertical pressure 100kPa

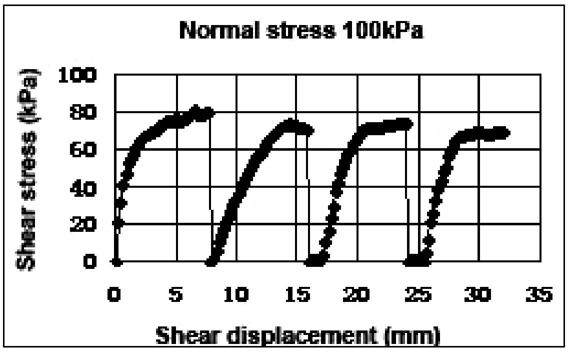


(b). The stress-strain curves under vertical pressure 200kPa

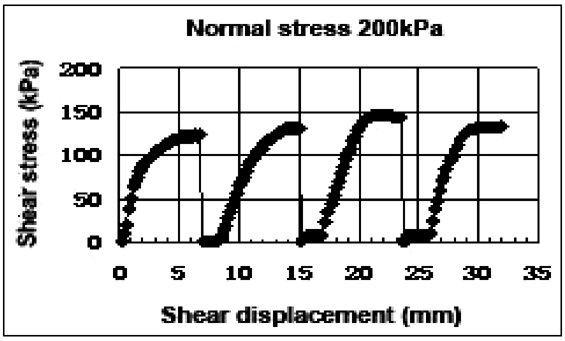


(c). The stress-strain curves under vertical pressure 300kPa

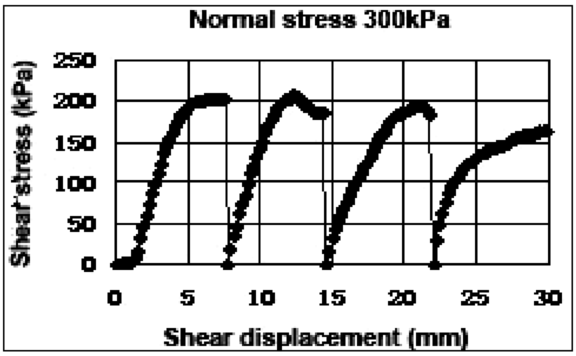
Fig .1 *Stress and strain relationship curves of Q_3 Loess under fully saturated conditions*



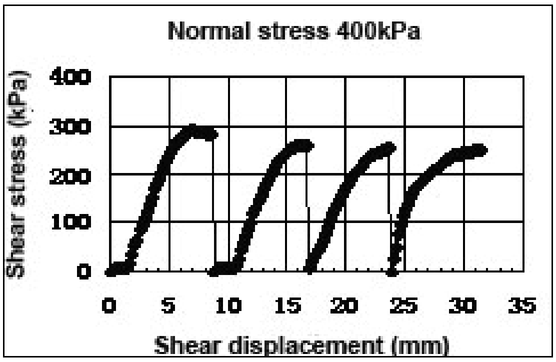
(a). The stress-strain curves under vertical pressure 100kPa



(b). The stress-strain curves under vertical pressure 200kPa



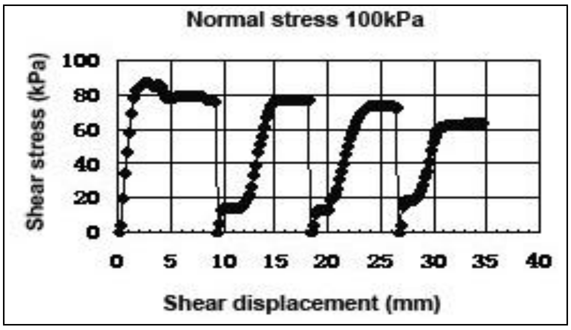
(c). Stress-strain curves under vertical pressure 300kPa



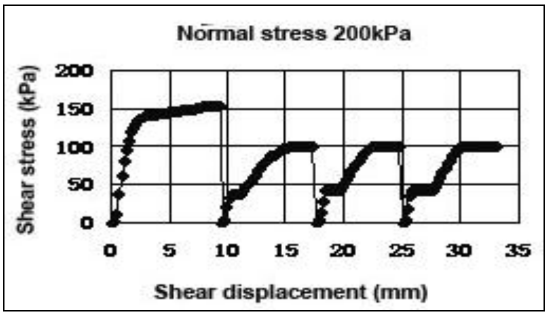
(d). Stress-strain curves under vertical pressure 400kPa

Fig .2 *Stress and strain relationship curves of Q_3 Loess under natural conditions*

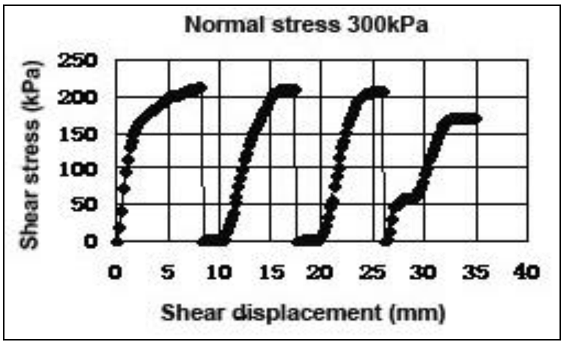
Figs. 1 and 2 reports the stress and strain curves of Q_3 Loess under different vertical pressure and different moisture content, by comparison and analyzing the curves the following conclusions can be concluded: the shear stress is increases along with normal stress increases. Under identical normal stress conditions, the shear stress under fully saturated conditions is significantly lower than natural conditions, under fully saturated conditions the shear displacement reaches its maximum value 43mm. The peak value of the first shear displacement curves and final shear displacement curves was defined as peak strength and residual strength, respectively. By comparison we found that peak strength and residual strength both increased as normal stress increased, and residual strength is significantly lower than peak strength.



(a). Stress-strain curves under vertical pressure 100kPa

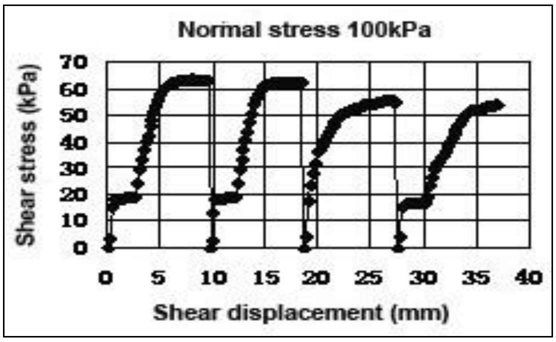


(b). Stress-strain curves under vertical pressure 200kPa

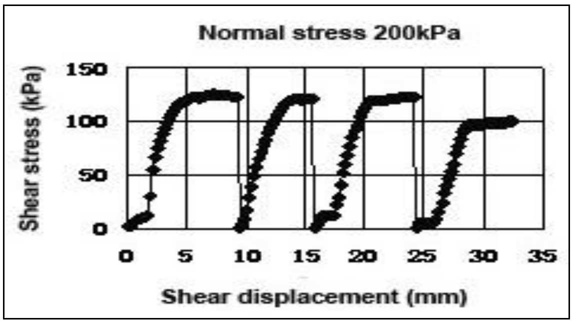


(c). Stress-strain curves under vertical pressure 300kPa

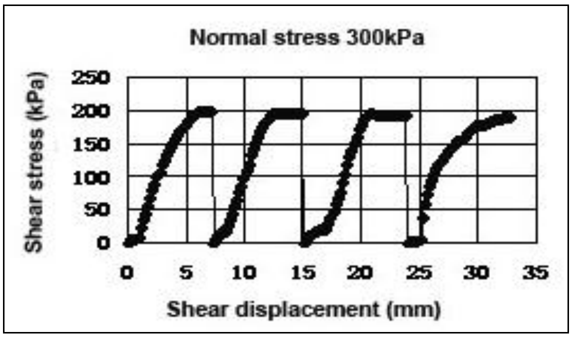
Fig .3 *Stress and strain relationship curves of Q_2 Loess under natural conditions*



(a). Stress-strain curves under vertical pressure 100kPa



(b).Stress-strain curves under vertical pressure 200kPa



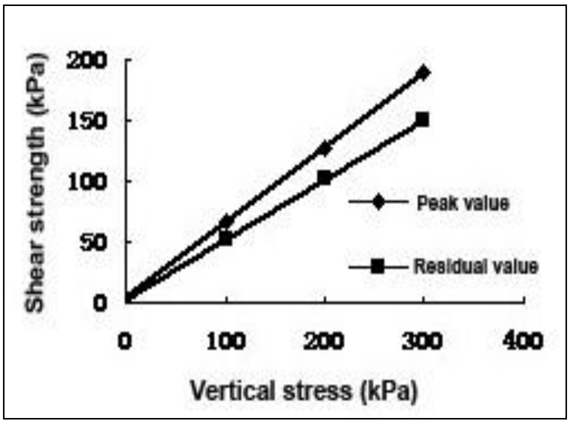
(c). Stress-strain curves under vertical pressure 300kPa

Fig .4 *Stress and strain relationship curves of Q_2 Loess under fully saturated conditions*

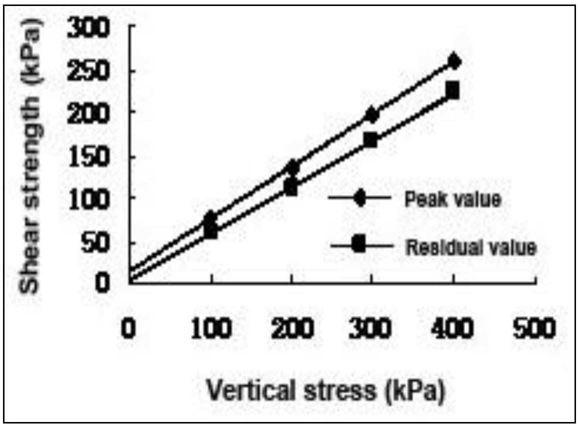
By comparison Fig .3 and Fig .4 we found that the laws of stress and strain under different normal stress are almost identical, residual strength is the intrinsic property of Loess soil, which is independent of soil stress histories. The strength of Q_2 Loess is greater than Q_2 Loess under identical normal stress, which signified that the engineering mechanical properties of Lishi Loess is a little bit better than other Loess, this is mainly determined by the climatic conditions during the process of soil formation.

3.2. The shear strength curves

Referred to stress and strain relationship curves, the peak stress of the first cut was taken as peak shear strength, and the peak stress of the last cut was taken as the residual strength, thus the relationship curves between shear strength and vertical pressure can be depicted (Fig .5 and Fig .6). The intercept of the curves on y-axis is the cohesion force, while the angle between x-axis and the curves is internal friction angle.

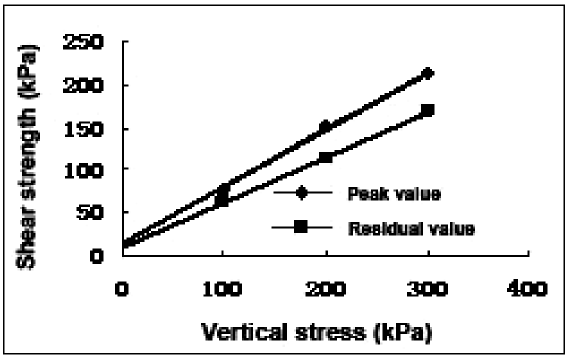


(a).Q_3 loess under fully saturated conditions

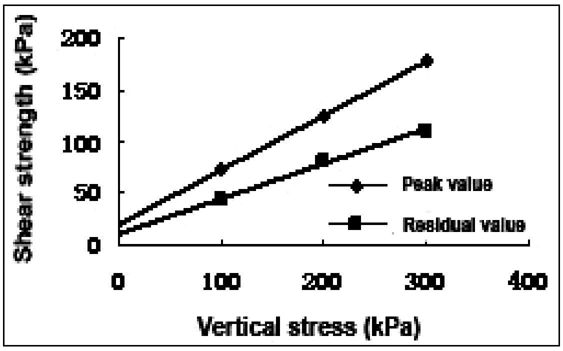


(b). Q_3 loess under natural conditions

Fig .5 *The relationship curves between shear strength and vertical pressure of Q_3 loess*



(a). Q_2 loess under natural conditions



(b). Q_2 loess under fully saturated conditions

Fig. 6 *Residual strength and peak strength under repeat shear tests*

Based on the aforementioned analysis, the shear strength under natural conditions and fully saturated conditions can be acquired, the results of the experiment referred to Table 1.

Table 1. *Natural and saturated soils shear strength parameter list*

Soil types	Natural conditions				Fully saturated conditions			
	Peak strength		Residual strength		Peak strength		Residual strength	
	c (kPa)	φ (°)	c(kPa)	φ(°)	c(kPa)	φ(°)	c(kPa)	φ(°)
Malan Loess	12.9	31.6	3.6	27.6	4.5	27.8	2.9	18.6
Lishi Loess	20.58	33.4	10.89	28.5	15.22	31.4	10.48	26.2

4. Conclusions

Comprehensively combined the experimental results with the phenomena during the experiment process, and meticulously analyzing the relationships curves between stress and strain, the following conclusions can be concluded: The strength of the Malan loess is significantly lower than the Lishi loess; under natural conditions, peak and residual strength both a little higher than their corresponding values under fully saturated. Along with moisture content increases, the cohesion force c decreases rapidly while internal friction angle φ only varied a little; For identical

Loess soils, the residual strength is significantly lower than the peak strength; moisture content played a multiple role in soil strength variation. Residual strength is the intrinsic property of soils, and residual strength is a stable value, regardless of soil stress history.

Acknowledgements

This work was financially supported by Doctoral fund at Henan Polytechnic University (Grant No: 72515/313), and by Doctoral fund at Henan Polytechnic University (Grant No.B2015-58).

References

[1]Yang X, Wang F, Bento CPM, Xue S, Gai L., “Short-term transport of glyphosate with erosion in Chinese loess soil—a flume experiment”, Science of The Total Environment, 512: 406-414,2015

[2]Zhou J-x, Zhu C-y, Zheng J-m, Wang X-h, Liu Z-h., “Landslide disaster in the loess area of China”, Journal of Forestry Research, 13(2):157-161, 2002

[3]Xu ZJ, Lin ZG, Zhang MS.,“Loess in China and loess landslides”, Chinese Journal of Rock Mechanics and Engineering, 26(7): 1297-1312, 2007

[4]Dekai LBW. “A new theory of space forecast for loess landslides”, Journal of gansusciences, 3: 120-126, 1998

[5]Ma D-t, Zhao S-x, Li H-L., “Study on the Landslides at the Edge of Loess Terrace in Yanguoxia Reservior Region”, Bulletin of Soil and Water conservation, 1: 11-17, 1995

[6]Fu B., “Soil erosion and its control in the Loess Plateau of China”, Soil Use and Management, 5(2): 76-82, 1989

[7]Zhang, M-S, Xiao P-X, Wei X-L.,”A preliminary discussion of the occurrence of landslide in the Baota district of Yan'an City”, Hydrogeology and Engineering Geology, 33(6): 72-74, 2006

[8]Liao HJ, Su Lj P., “Testing study on the strength and deformation characteristics of soil in loess landslides”, Proceedings of 10th International Symposium on Landslides and Engineered Slopes, 443-447, 2008

[9]Bai M, Du Y, Kuang X, Cheng G., “Warning method and system in risk management for loess engineering slopes”, Journal of Performance of Constructed Facilities, 26(2): 190-196, 2011

[10]Li T, Wang P, Xi Y., “The mechanisms for initiation and motion of Chinese loess landslides”, Progress of Geo-Disaster Mitigation Technology in Asia, 105-122, 2013

[11]Wang Z-r, Wang N-q.,“A Summary of Present Study on Loess Landslides”, Soil and Water Conservation In China, 11: 103-110, 2004

[12]Ji B, Xu C, Li J, Jiang R-B, “Study on Classification and Distribution Regulations of Loess Slope Slides along Highway in Shanxi Province”, Technology of Highway and Transport, 1:11-13, 2009

[13]Hamel JV., “Residual shear strength mobilized in first-time slope failures discussion and closure”, Journal of Geotechnical and Geoenvironmental Engineering, 130: 190-196, 2004

[14]Kimura S, Gibo S, Nakamura S., “Estimation of Average Shear Strength Parameters along the Slip Surface Based on the Shear Strength Diagram of Landslide Soils”, Transactions of The Japanese Society of Irrigation, Drainage and Rural Engineering, 78: 445-453, 2011

[15]Zhang D, Wang G, Luo C, Chen J, Zhou Y-X.,“A rapid loess flowslide triggered by irrigation in China”, Landslides,6(1): 55-60, 2009

[16]Xiangyi L., “The hazards of loess landslides in the southern tableland of Jingyang County, Shaanxi and their relationship with the channel water into fields”, Journal of Engineering Geology, 3(1): 56-64, 1995

[17]Derbyshire E, Dijkstra TA, Smalley IJ, Li Y., “ Failure mechanisms in loess and the effects of moisture content changes on remoulded strength”, Quaternary International, 24: 5-15, 1994

[18]Zhang C-l, Wang A-D, Xing X-l, Li T-L, Li P., “Research on mechanism of loess landslides caused by erosion”, Rock and Soil Mechanics, 33(5): 1585-1592, 2012

[19]Xu L, Dai F, Min H., “Research Progress and Some Thoughts on Loess Landslides”, Advances in Earth Science, 3: 35-41, 2008

[20]Wang J-J, Liang Y, Zhang H-P, Wu Y, Lin X., “A loess landslide induced by excavation and rainfall”, Landslides, 11(1): 141-152, 2014

[21]Cruden DM, Varnes DJ., “Landslides: investigation and mitigation. Chapter 3-Landslide types and processes”, Transportation research board special report,1996.

[22]Li TL, Long JH, Li XS., “Types of loess landslides and methods for their movement forecast”, Journal of Engineering Geology, 15(4): 500-506, 2007

[23]Tu XB, Kwong AKL, Dai FC, Min H., “Field monitoring of rainfall infiltration in a loess slope and analysis of failure mechanism of rainfall-induced landslides”, Journal of Engineering Geology, 105(1): 134-150,2009

[24]Wei-sheng W, Xin W., “Distribution regularity and forming condition of loess landslide”, Journal of Catastrophology, 2: 15-23, 2001