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Abstract: This paper emphatically introduces a new landslide's stereoscopic monitoring systemm that was builded in Xintan slope after failed. The movement in the underground different level can be decided through monitoring of surface by the system. The system can provide a basis to master the slope gliding regulartion so that a new prediction method may be worked out in the future.

INTRODUCTION

In the time from 3:45 to 4:20 Am. 12th.June,1985 the slope from the north of Xintan village to Guangjia cliff failed wholly within the Zigui County of Hubei, China. The slipping volume is totally accounted for about $3.0\times10^6M^3$ which destroyed Xintan village completely. About $3.0\times10^5M^3$ slipped soil-rock of the total,rushed into the Changjiang River,causing a swell wave of 50M higher, which has a influence range in the River from upper, Zigui, (15KM away from the accident) to lower, Sandouping(27KM). Fortunately,no resident was killed since accurately predicted by the researchers based on the information accumulated by a twenty year's research work and achievements. Therefore, 1,300 inhabitants were able to leave the dangerous zone all before the event happened. This is really a miaracle in the world landslide's history.

Xintan slope is an accumulation slide. The materials are mainly from Guangjia cliff, Jiupan mountain and Huang cliff.Xintan slope's monitoring is necessary after the incident since Guangjia cliff and Jiupan mountain have still several million cubic meters dangerous rock masses and slip-fall is possible. It is belived from the point of view of ours that Xintan slope previous measurement was mainly done on the earth's surface and as a result, it is hard to refect comprehensively what happens in the real situation, espcially, to look for slip surface, confirm the type of slide and study slide movement cause.For this reason, a new stereoscopic monitoring system was builded up in Xintan in July, 1989. The system and some initial analysis conclusions from monitoring datas will be main interest of this paper.

1.THE GEOGRAPHICAL POSITION AND GEOLOGICAL CONDITIONS OF XINTAN SLOPE

Xintan slope , in the north of old Xintan village, at upper section of Xiling Gorge, by the mouth of Bingshu Baojian Gorge, on the opposite to the dangerous rock masses of Lianzi cliff at the Changjiang River's south coast. 72KM distance to Yichang city at lower, 28KM to Sandouping where will be builded Sanxia big dom, is a famous dangerous zone of rock fall-slip(Fig.1).

Xintan slope is made of soil and rock mixture, has several ten meters thick, about 2,000 meters

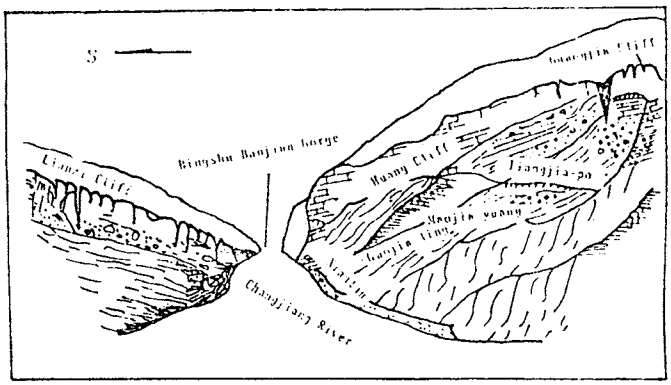
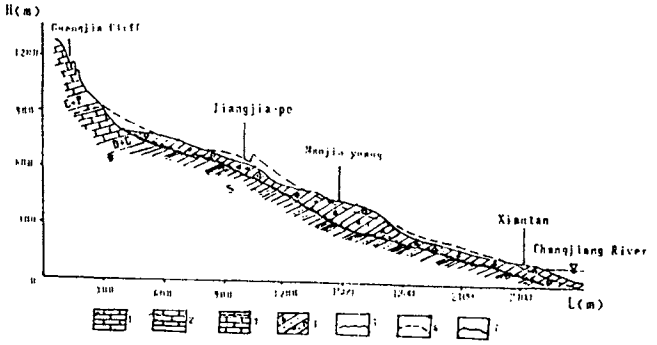


Fig.1 Sketch about movement areas of Xintan slope and Lianzi cliff

long, several hundred meters wide, the width and thickness change from place to place.The material forming the slope is mainly from Guangjia cliff and Jiupan mountain which was collapsed year by year. And this is caused by concentrated cracks, weathering action, mining coal underground and other human activities. The whole slope is like a wedge in the shape, with a narrow top (300M) and a wide bottom (500~1,000M), dipping to the Changjiang River. The slope's gradient changes differently,which forms a shape like a ladder. The steep slope is 40 degress with the general ranged 20~25 degress. The composition of the slope is mainly limestone, silicastone, sandstone and clay(Fig.2).

The westen boundary of Xintan slope is Huang cliff which is a shear precipice and overhanging rocks, with highth about 100 meters, which is made mainly of mainly of limestone and sandstone. The easten upper section boundary is a longitudinal steps of old fall accumulation and lower is a long narrow mound area which was produced by the si de-extruding of slope's gliding.

The sector from Guangjia cliff to Jiangjia-po, about one half of whole slide's longth, universal thought, is a leading slip zone of last slipping, and the landslide is cut off at 470M level. The slope from 470M level to the Changjiang River's north coast is a forced slip zone.



1-the Carboniferous Permain Peried limestone and coal measures(C+P)
2-the Devonian and Carboniferous Peried shale and sandstone(D+C)
3-the Shurlan Peried sandstone and shale(S)
4-the Quaternary Peried old fall-slip accumulation(Q)
5-boundary of bedrock
6-the earth's surface line of slope before failed
7-the earth's surface line of slope after failed

Fig.2 Geological longitudinal section of Xintan slope

The last slipping may be a total slope's gliding according to remaining marks of the earth's surface.

The shaft, at 500M level,shows that the thickness of the rock masses is 25.5 meters and there are five layers in the formation along the shaft depth. The rock masses are mainly light grey and grey-black limestone blocks. The marks of layer and layer, besides, obvious different composition, is that there is a thin yellow sub-clay or sandy soil layer.The condition parameter of every layer's interface is those as table 1. The slide

Table 1. Condition parameters of accumulation layer

depth of layer's interface (meter)	condition of interface (degree)	thickness of clay and sandy soil in interface (centimeter)	remarks
15.1	280<45	sub-clay 10~15	/many /slicken-
16.2	270<45	sandy soil 10~15	/sides /that point /out the slip
25.5	260<26	23.7~24.7M,clay accumulation, 24.7~25.5M , violet-red clay layer	surface in violet-red clay layer ,the slip direction is NE30 degress
30.3	275<25	not weathered bedrock under 28M in the shaft	

accumulation has a good permeability. There is only a little of water oozing on the clay layer at bottom of accumulation. There are many slickensides that point out slip driection , NE30 degress, in 80 centimeters thick clay layer on the bedrock.

The slope's bedrock is made of Shurian Perio sandstone and shale. The whole slope has a tend ency of density increasing,pereability and aper ture reducing progressively from the surface t the underground and from Guangjia cliff to th Changjiang River.

2. XINTAN LANDSLIDE'S STEREOSCOPIC MONITORING SYSTEM

The keys of stereoscopic monitoring system ar to build a grid of surface and underground move ment measurement in Xintan slope, try to make comprehensive analysing and treating system o combining the geometric changes observed on th earth's surface with the physical changes in th underground, and causing the system can be use to analyse comprehensively the slide in man ways.

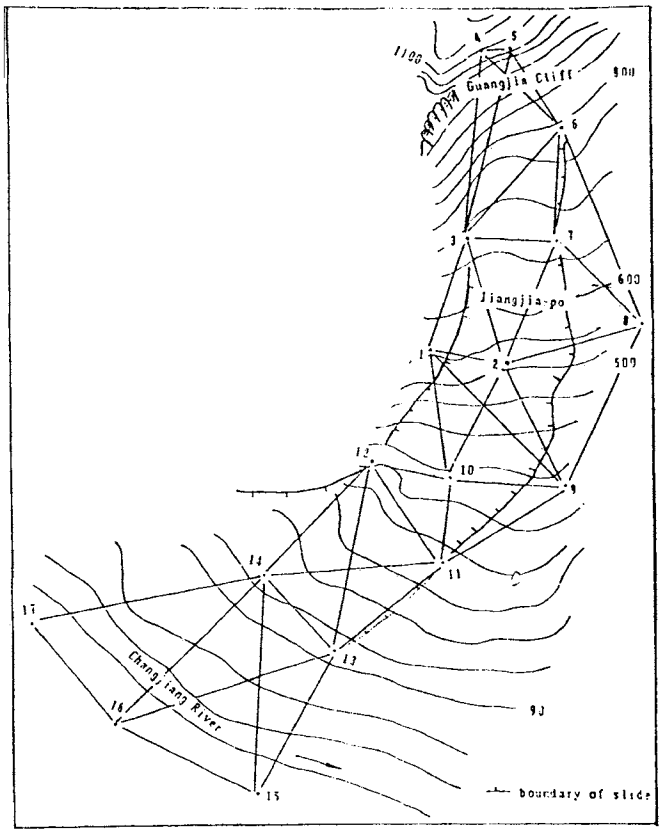
1) Method of surface survey

According to the condition of Xintan slope, complicated landform, with the highth more thar 1,000 meters from the top to the bottom,workin condition hard and dangerous, the surface survey employs multiple triangle locks of electromagent wave-range finding as main method and close shot photogrammetry as complementary measure. The information is obtained by using new instrument (fast surveying instruments of ELTA-2 type made by West Germany and TC-2000 type by Switzerlanc ; photographic instruments such as NMK 30/1318 and 20/1318 both made by East Germary). The resulted datum is treated by using guide of modern even deviation theory. The slope surface various regulartion is analysed by a appropriate and new mathematical model which is obtained by studing the site condition in many ways.

The whole slide surface is builded the triangle locks of electromagnet wave-range finding with seventeen surveying points(Fig.3). The grid for close shot photogrammetry has two section one is made of twenty points of photogropty survey at upper, the area of Guangjia cliff danger ous rock, the other is made of sixty points a lower, the area under 500M level.

2) Method of underground monitoring

The underground monitoring is done through excavating shafts on the slope and installing instruments in shafts.So departing characyeristics of whole slide must be considered to select the shaft sites, at the same time, there should be representertive. Through analysing geological materials and invertigating on the slope, the underground monitoring points are installed on 500M and 165M level. For 470M level is the cutting mouth of the principal slide sector of last slipping, 500M level is the intersection site of the leading slip area and resistencing slip area , the site of 165M level is the slip tongue of total slide, both are stress concentrated area and very sensitive to slipping, installed monitoring points on these sites can take a good effect. Above all, the underground monitoring is undertaken through installing instruments in two shafts, one is a 30.3 meters depth on 500M level and another is a 50 meters depth on 165M level. This paper will stressly instroduce the monitoring situation of the shaft on 500M level. Six contingents of WY type displacement transducer, four contingents of bowstring type many dots displacement gauge and six contingents of WL-60 type prizometer are installed in the shaft on 500M level.The surface and underground is binded by a



ig.3 Sketch map of surface survey triangutation

anging hammer, installed at the top of the shaft. nstalling of instruments in the shaft on 165M evel seems to that on 500M level. In installing onitoring instruments, the stereoscopic effect s stressly considered, at the same time, following factors are considered:

(1) According to the engineering geological investigation of the shaft on 500M level, the slip urface of last failed at 25.5 meters depth site. t will also be possible to glide along near the lip surface. For every clay or sandy soil layer bove 25.5 meters along the shaft on 500M level s thin, the lefts are the accumulation of rock locks, a slip surface is difficult to be formed n this layer. So it is needed to install monitoring points at 25.5 meters of the shaft depth up nd down.

(2) From the condition parameters of all accumulated layers (table 1), known that the layer urface condition on 20.7 meters site is the ame as that on 25.5 meters site, the lefts are he same as that of bedrock. So the focal point f monitoring site is below 20.7 meters depth of he shaft.

(3) For grasping the regular of shaft's displacement transfering, there are at least three groups instruments of horizontal displacement survey installed in the shaft. At the same time, considering to gauge slip direction, every group instruments of horizontal displacement survey can't be less than two contingents, and all is installed in NE30 degress direction.

(4) In order to survey the motive force of the slip surface up and down and the principal stress direction, prizometers shoud be installed near the possiblest slip surface, every group prizometers can't be less than three contingents.

Finally, installing of instruments is those as figure 4 and table 2.

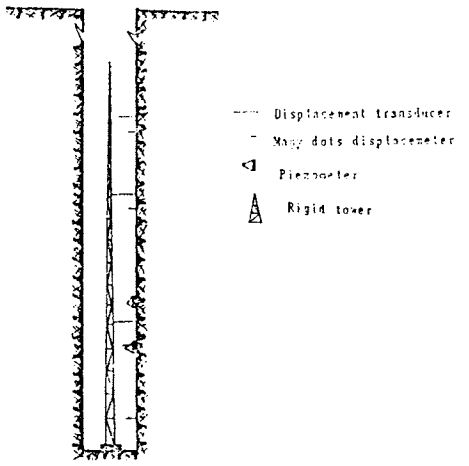


Fig.4 Sketch of instruments installed in the shaft

Table 2. The sites and direction of underground monitoring instruments installed

name of instrument	number	depth (meter)	direction (degree)	monitoring content
WY type displacement transducer	1	17	NE53	horizontal displacement and slip direction
	2	17	NE23	
	3	20	NE5	
	4	20	NW25	
	5	25	NE65	
	6	25	NE35	
WL-60 type prizometer	1	23.6	NE35	horizontal motive force and principal stress direction
	2	23.6	NE80	
	3	23.6	ES35	
	4	27	NE31	
	5	27	NE76	
	6	27	ES31	
many dots displacemeter	1	18	NE44	subsiding displacement
	2	21	NE44	
	3	26	NE44	
	4	30	NE44	

3 MONITORING DATUM ANALYSING OF XINTAN SLOPE'S STEREOSCOPIC MONITORING SYSTEM

The surface survey of Xintan slope's stereoscopic monitoring system started in 1987, the underground monitoring started in 1989.

1) Analysis of the surface surveying datum

The works of the surface survey, besides using conventional measuring means, monitoring the surface movement and analysing the stability of the slope, the strain analysis of the slide with the surface measuring datum is done. By analysing the surface measuring datum about three years, it is found that the slip zone of the Guangjia cliff has massive slide in patient. There are slow and obvious slip areas under the fractures of Guangjia cliff. The whole slipping tendency is SSE direction. And the average slipping speed of the obvious slip area is 1 centimetre a month. The average displacement variation in Gaojialing and along the River zones under 500M level is about 8 centimeters a year. The strain analysis is done using the datas of surface survey, at the same time, the seventeen triangles's strain parameter is examined, and the remarkable takes 76.5%. According to the analysis of the strain, the principal strain variation of the triangles, lying in the coasts of the Changjiang River, is relatively small, the triangles area become small, it says that movement of this area is small. Regarding 8-2-1 points at Jiangjia-po as boundary (Fig.3), to the north part slip masses, the principal compressed strain is greater than the principal stretched strain, the strain situation is NW degress compressed rightspin shear, to south part slip masses, the principal stretched strain is greater than the principal compressed strain the strain situation is NE45 degress stretched leftspin shear. All these monitoring results are consistant with that of the underground monitoring which will be intruduced in following.

2) Analysis of the underground monitoring datum

The underground monitoring, comparing to the bedrock, is measuring the variation of horizontal, subsiding displacement and stress in the different depth of shaft. The typical curves obtained through measring are those as Fig.5(a) (b) (c) (d). From these curves, we known that:

(1) From the view of the monitoring datum between September, 1989 and April, 1990, the subsiding displacement of the mouth of the shaft relative to different depths increases as temperature dropping, but it variation is small, and it fluctuating range is from -0.7mm to 2.5mm. From the view of its varying trend, the upper accumu-

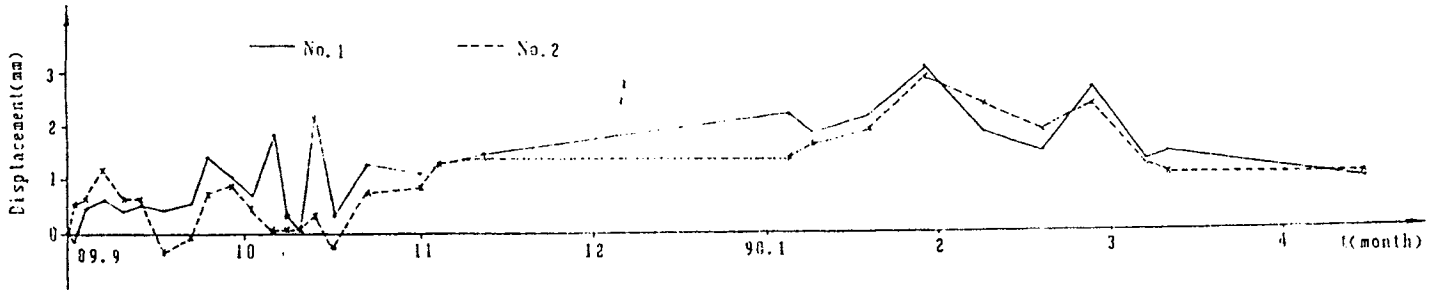


Fig.5(a) Typical curve of Xintan slope's subsiding movement

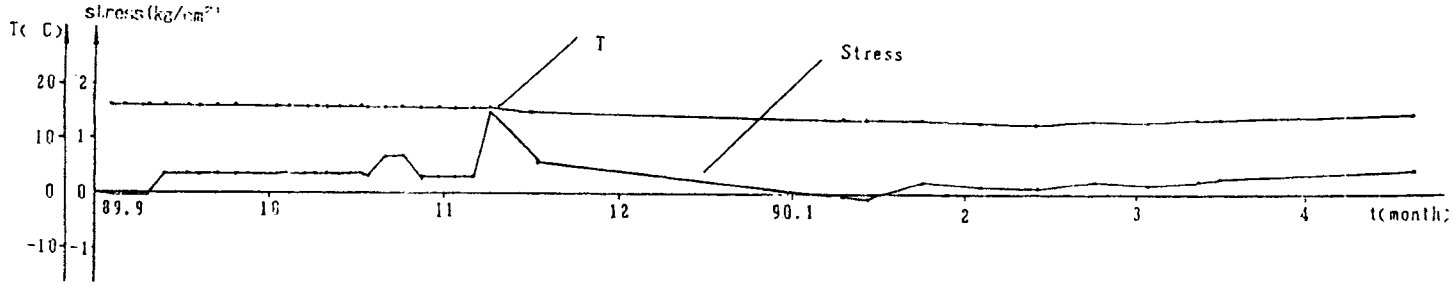
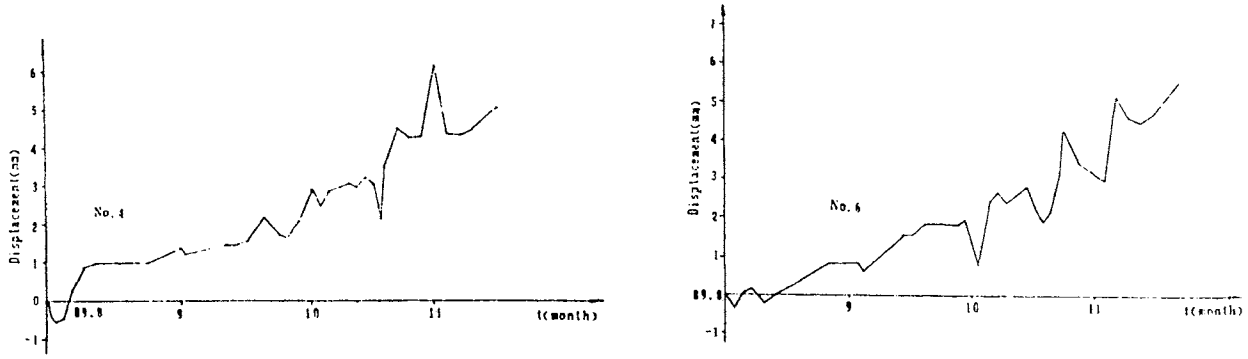


Fig.5(b) Typical curve of Xintan slope's stress and temperature



(c) (d)

Fig.5(c) (d) Typical curve of Xintan slope's horzontal movement

ation masses are compacted further. The total ubsiding displacement of the mouth of the shaft elative to 18M, 21M, 26M and 30M depth in the haft is separately: 0.806mm, 0.869mm, 0.285mm nd -0.515mm, and it illustrates that the move- ent of the slope is much small.

(2) From the view of the monitoring result of izometers about nine months, the variation of he motive force on the pit of shaft is much mall. By caculating the monitoring datum, the ccumulation up the old slip surface, the prin- ipal stress variation is 0.613 kg/cm², its rientation is NE10 degress, down the slip sur- ace, the principal stress variation is only .057kg/cm², and orientation is NE66.7 degress. t is know from these, the slide masses up he old slip surface in 25.5 meters depth of the haft is still given a centain extent of motive orce.The principal stress direction is analysed hrough using the monitoring datum, it is found ts variation is ordinarily within NE10~34 de- ress, and this is consistent with the rubbing arks found on the old slip surface and the moni- oring results on the surface. From the view of he monitoring typical stress curve, there is no reat movement in the slope at present.

(3) The displacement transducers are the major onitoring instruments of this system.Shown from igure 5(c)(d), the horizontal displacement is ncreasing step by step. Caculating by the moni- oring datum, the accumulation's horizontal dis- lacement and the principal slip direction are eparatedly: 5.12mm, NE19.6 degress; 5.06mm, W29.4 degress; 6.22mm, NE20.4 degress, in which s 17M, 20M, 25M depth of the shaft. All these esults are comparatively consistent with the esults of the surface measuring and the rubbing arks with direction of NE30 degress in the haft. From the view of the monitoring results, the displacement variation is not great, but it is worth to be noticed that the displacement various rate has a trend of increasing.

3 THE SHAFT DISPLACEMENT TRANSFERING FUNCTION

The aim of creating displacement transfering function is in order to understand deeply the regular of development of displacement in different depth underground,make the monitoring of surface and underground can be analysed and treated in the same coordinate system. It had never been done previously, moreover,it can provide a basis for creating a new prediction method.

The displacement transfering function needs reflect the various relationship of the displacement along with the depth of the shaft. Thus,the function may be created as U[u,h,t], obviously, variable u, upper displacement, should also be the function of time(t). Certainly, U or u is also influenced by these factors, such as geological condition of the slope,earthquake,underground water, surface water etc. However,for the same landslide, obviously,if the influence of the fortuitous factors,like earthquake etc., are neglected,the variable u will be completely regarded as the function of time(t) and rainfall(Q), that is u(t,Q). So the general displacement transfering function can be expressed as U[u(t,Q),h,t]

If the influence of irregular rainwater is not considered, the transfering function can also be written as U[u(t),h,t].

The stereoscopic monitoring datum are arranged and analysed according to the function type of U[u(t),h,t].The value of ratio of the horizontal displacement along with the depth of the shaft has excellent regularity. So the various relationship of displacement transfering function U[u(t),h,t] along with time(t) can be completely refected through the implicit function of upper displacement u(t). And the transfering function can be written as

$$U[u(t),h,t]=U[u(t),h]=u(t)\cdot K(h) \quad (1)$$

where u(t) is the function of upper displacement variation along with time,K(h) is the regression curve of the value of ratio of every horizontal displacement under the shaft to upper.

After the variation of upper displacement is transfered into the displacement of the principal direction, NE30 degress,the monitoring curve and imitation curve are shown in Fig.6,the imitation function is

$$u(t)=0.477e^{0.022t} \quad (2)$$

With the points distribution diagram of the

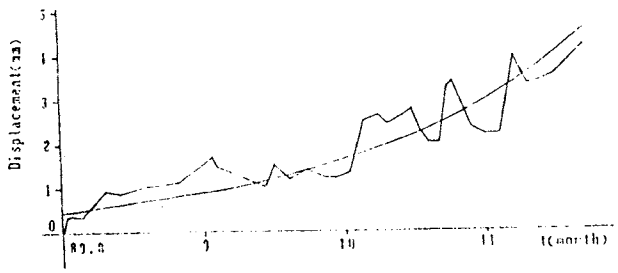


Fig.6 Measurement and imitation curve of Xintan slope's horizontal movement

value of ratio of monitoring, K(h) can be regressed as

$$K(h)=0.013h^2-0.545h+6.402 \quad (3)$$

then the displacement transfering function is

$$U[u(t),h]=0.477e^{0.022t}(0.013h^2-0.545h+6.402) \quad (4)$$

Finally, the gliding regulars of the landslide in the period of time has been known. Here, one point must be illustrated, due to the monitoring datum underground not being enough plentiful,the displacement transfering function will need to be perfected further as monitoring times passing and the datum accumulated, and make to be popularized and forecast landslide joining the natural relations of rock-soil of slip layer.

CONCLUSIONS

(1) At present, Xintan landslide is stable according to the monitoring results,the movement of the accumulation masses is not great, but it has accelerating trend.

(2) The slope trends to glide along the last old slip surface and the principal slip dirrction , about NE30 degress.

(3) With the creation of displacement transfering function,it is possible to make the monitoring of surface and underground research in the same coordinate system and provide a basis to work out a new slide prediction method

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