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LANDSLIDE MECHANISMS OCCURRED IN A COLLUVIUM SLOPE DEPOSIT

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SUMMARY; A case study was conducted at a landslide located on an ancient colluvium deposit. The mechanism of this specific landslide involves a weak sandy clay layer together with seepage force exerted by groundwater flow during large rainstorm.

1. INTRODUCTION

The emphasis of this study is to determine the cause of a landslide in a colluvium slope through the long-term monitoring.
The correlation between rainfall and groundwater level together with the variation of groundwater level during the rainstorm are also be investigated . Laboratory investigations include the simulation of the composition of soil particles for in-situ conditions and the estimatiom of the cohesion and the angle of internal friction by shear tests. Through these investigations, in-situ monitoring system, and latoratory studies, the mechanical characteristics of the colluvium slope deposit are determined. The results can then be applied to other sites with similar conditions found in other places on the central Cross Island Highway, Taiwan.

The procedure of this research is shown as fig. 1.

2. STUDY SITE

The study site is on the 7-A subline 72K+500 of the Central Cross Island Highway to Ilan(Fig.2). Land use of the area is fruit tree plantations. The landslide has continued for a long time. And the only control practices are a drainage system and the retaining wall with

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the height of 1.4m and length of 20m(Fig.3). When rainfall continues for several days, a small pond forms at the base by seeping water.

Geology in the area is the Lushan formation of Cenozoic on a pre- Tertiary metamorphic basement. The Lushan Formation is composed of argillite, slate, the phyllite and sandstone. The study site located upstream from Ta-Chia River and on a deposit caused by previous erosion and sliding. Land slope ranges from 15 to 30 degrees. Annual precipitation averages 2259.9mm. The largest annual rainfall amount recorded was 4988mm in 1950.

3. FIELD MONITORING AND INVESTIGATION

3.1 Monitoring

3.1.1 Precipitation

A recording raingage was installed at the site and monitored at 30 day intervals. The highest daily rainfall is 200mm in April 19, 1990, and the highest monthly rainfall occurred in the same month with 960mm. Measurement of precipitation last for 12 months, and the total rainfall is 2540mm.

3.1.2 Ground water level

Groundwater is a major problem for slope instability. When ground -water exists in a slope, the slope will be unstable due to decreased soil cohesion, increase in pore water pressure, the formation of press -ure, the formation of uplift forces, and the reduction of shear resistance at the sliding surface. Therefore, the variation of groundwater level is the major determining factor of landslides.

In this study, two drilled holes, located in A-1 and A-2 (Fig.3), were set up to measure the variation of groundwater level. The depth of holes A-1 and A-2 were 20 and 13m, respectively. After the drilling, 5cm PVC protective casings were buried with open holes in the bottom and walls of the lowest were packed with geotextile.
An automatic water level gage was situated on a concrete stand on top of the well. The cycle of recording was 30-day, the same as the rainfall gage.

During the measuring period, the maximum variation of groundwater level occured in September, 1989 during typhoon Sarah. Totle precipitation was 400mm during three consecutive days and the groundwater level rose about 50-60cm (fig.4). In October, 1989, both of the protective casings distorted and measurements were interrupted.

3.1.3 Sliding

Traverse surveys were conducted at the slide site . The datum point was set up in the front of Lishan , established out of the range of sliding, and 20 traverse points were at the same time. The results indicated that the upslope direction of sliding was southwest and downslope disection was northwest.

Depth of the sliding surface was estimated from the position of distortion of the PVC casings. In October, 1989, the position of distortion depth for A-1 was at 5.85m from the ground surface, and that for A-2 was at 5.57m (Fig.5). Consequently, sliding surface is nearly parallel to the land surface in this area.

3.2 Field Investiagtion

Data for density, water content and particle distribution, in colluvium,were obtained from samples excavated from a open cut. After that, a circular test well was drilled to investigate the composition of the colluvium material.

3.2.1 Sampling in the open cut

A site near A-1 and A-2 was selected for sampling. Vegetation and top soil to a 60 cm depth were removed with 60cm in depth was also removed. The procedures of excavation ofthe test well and the description for geology are as follow(Fig.6) :

a).0-0.6m: top soil

All things in this zone were removed in open cutting.

b).0.6-2.4m: slate-gravel

In open cut at A-1, the soil particles were sampled from 0.6m to 1.6m, which the Dmax is 18cm. The particle size was larger in deeper zone . Dmax for the zone was about 30cm. Since the seeping water existed at depth of 2.1m, 2.15m, 2.3m, and 2.4m , the path of groundwater level may be related to the pore space formed by the larger particles.

c).2.4m-4.2m: mixture of clay, rock, debris, and detritus

From 2.4m to 3.3m is the slate-clay soil particle size is <5cm and the seeping water occured at 2.7m. The zone from 3.3m to 3.7m contain a mixture of clay and slate (Dmax>50cm). The mixture of clay, rock, debris, and debritus located from 3.7m to 4.2m had average particle size smaller than 15cm with seeping water at 3.85m and 4.5m .

d).4.2m-5.9m:

The formation in this zone is composed of gray rock, gravel, and debris. The permeability is high and Dmax is about 32cm.

e).Below 5.9m: sandy clay layer with debris.

4. TEST FOR SOIL CHARACTERISTIC

Soil physical characteristics measured in the laboratory includes water content, bulk density, liquid and plastic limit, and graded aggregate. The resistance of the colluvium to weather is measured by a slake durability test. Specimen of colluvium for tests were prepared with bulk density(rd) of 1.745t/m and water content(w) of 13.99%.

The large scale direct shear apparatus was used in the CU (consolidated-undrained) test, which the grain size of the specimen was prepared with sieve size of 5cm,2cm, #4, #8, #16, #30, #50, #100, and #200. Results of the tests are shown in fig.7 and fig.8 which c=0.03kg/cm , ϕ =35°02 for the specimen of Dmax =5cm and c=0.35 kg/cm, ϕ =21.56 of Dmax=2cm.

5. STABILITY ANALYSIS

The landslide site was analyzed using PC STABL5 to ascertain the triggering mechanisms. The following inputs are required for the PC STABL5 analysis :(1)geologic profile,(2)groundwater level,(3)geology of the formation,(4)failure surface,(5)soil parameters.(including the unit weight and strength parameters).

Section A-A was chosen for the geologic profile analysis. All the assumptions for the computation were determined from the investigation and monitoring. Soil parameters obtained from the test in the lab were shown as follow:

(1)colluvium material: r=1.989t/m ,c=0kg/cm , ϕ =35°

(2)sandy clay layer: r=2.235t/m ,c=0.21kg/cm , ϕ =9.15°

6. CONCLUSION

Because the groundwater level between A-3 and A-1 differed about 9m, This implies that two or more groundwater zones exist. In the direct shear test, C increased as the content of fines in specimen increased. When the content of fines was more than 60%, the variation of C was less(Fig.10) , and the value approached a constant when the content of fines was more than 78% (Fig.11). The factor of safety (FS) of slope stability was obtained after the analysis of PC STABL5 , which F.S.= 0.82 (Fig.9).

The causes of this specific landslide can be attributed to the fo-llowing factor:

(1)the poorness of the drainage systems which differs the groundwater level of shallow stratum.

(2)poor ground surface covering which increase the infiltration.

(3)heavy transportation load.

(4)the weak sandy clay layer forming the sliding surface.

(5)the seepage force exerted by infiltrated groundwater flow.

(6)weathering of the colluvium material which decrease the shear strength of it.

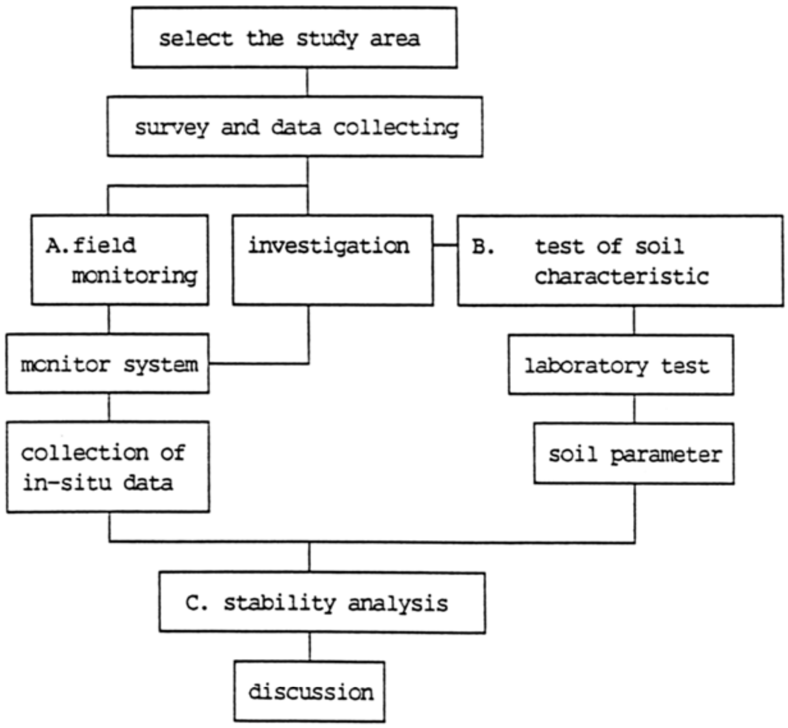

Figure 1. Flow net of this research

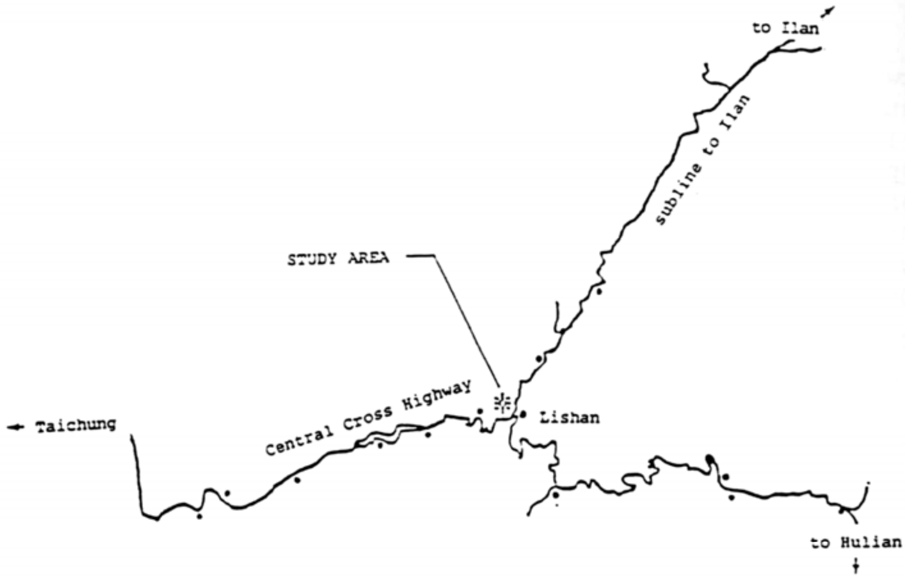

Figure 2. Location of sliding slope of this research

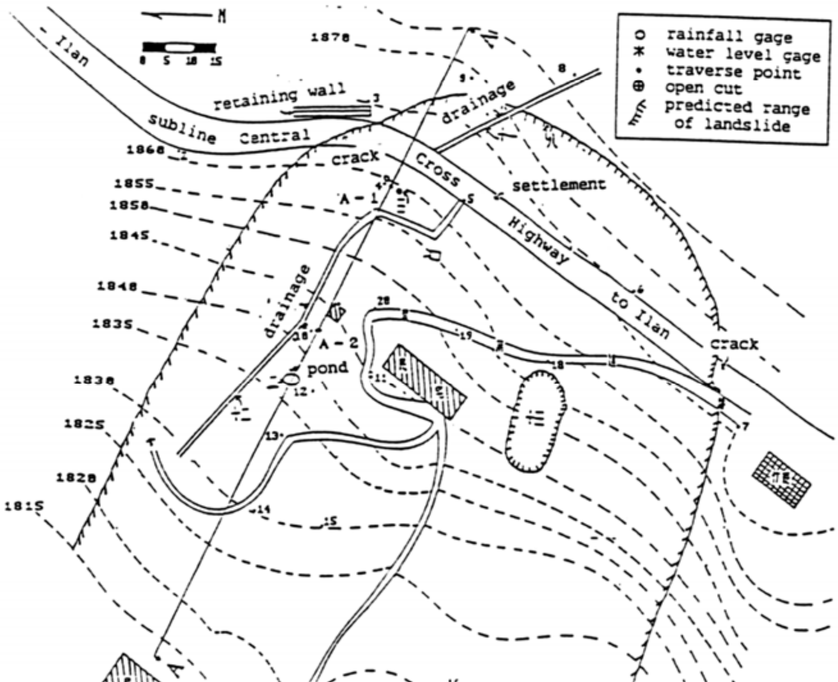

Figure 3. Study area in 72K+500 in Central Cross Highway

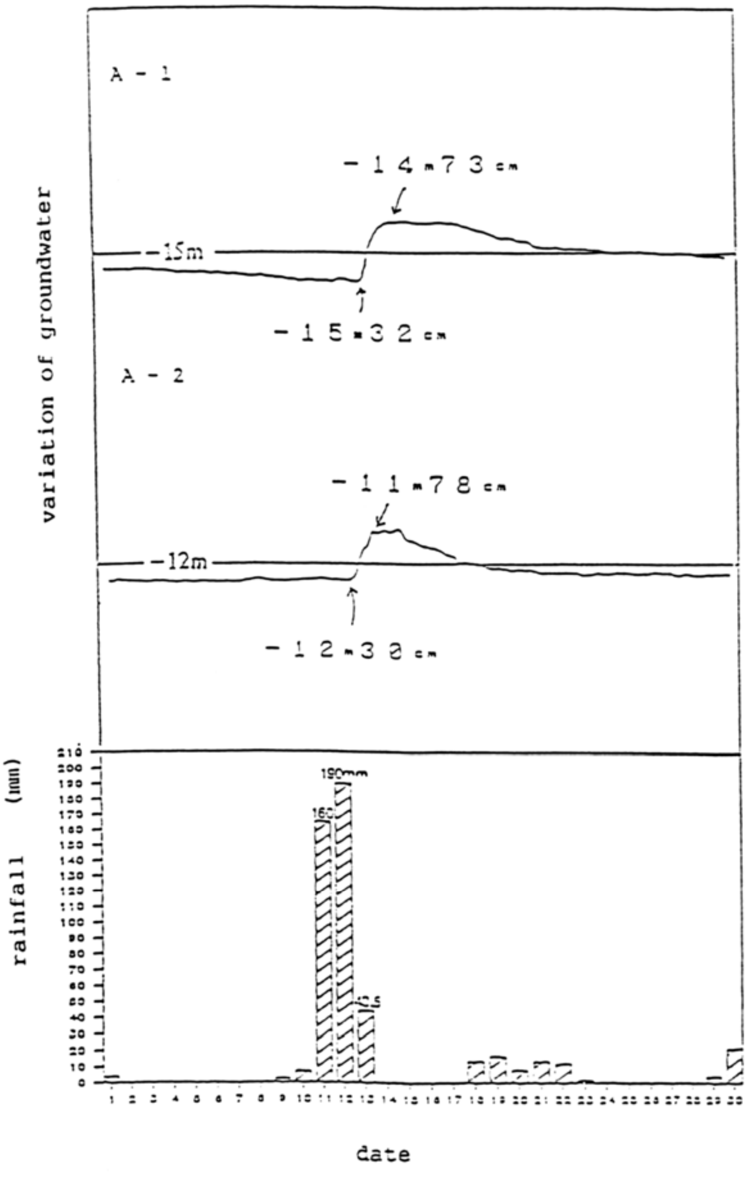

Figure 4 . Rainfall-Ground water level relationship during September, 1989

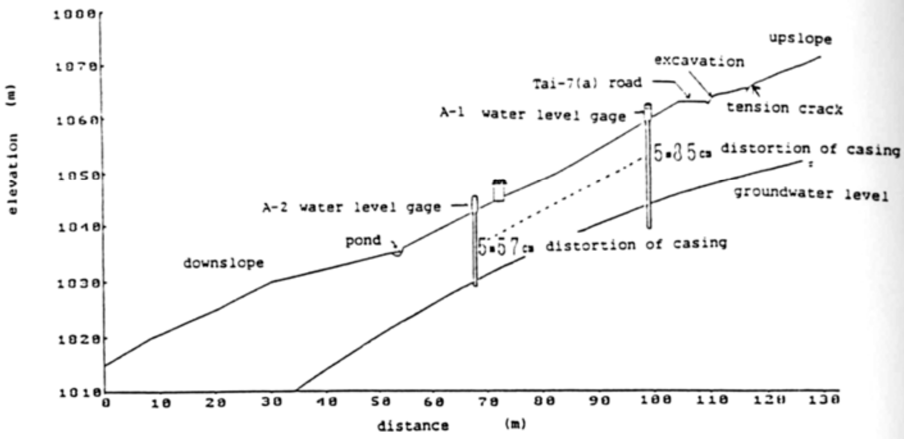

Figure 5. Measuring result of sliding surface of section A - A

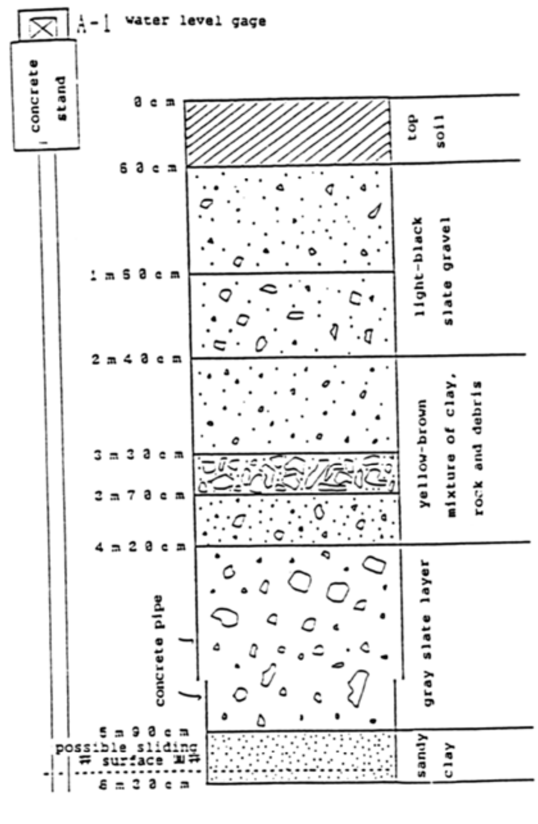

Figure 6. Diagram of test well

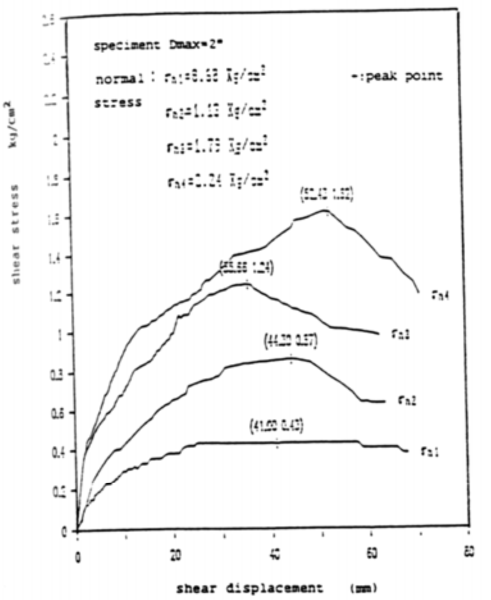

Figure 7. Result of large scale shear test of colluvium
- Shear stress vs. shear displacement

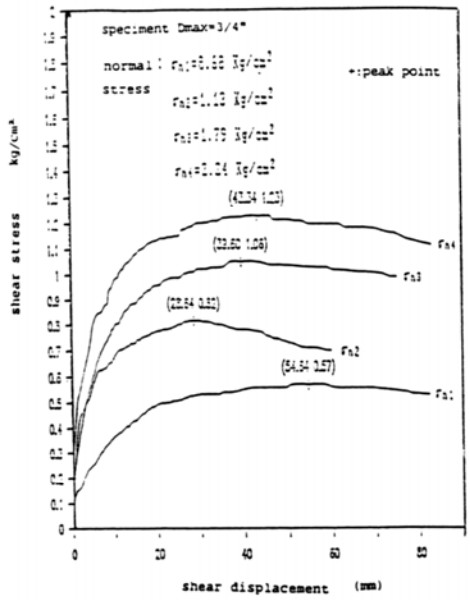

Figure 8. Result of large scale shear test of colluvium
- Shear stress vs. shear displacement

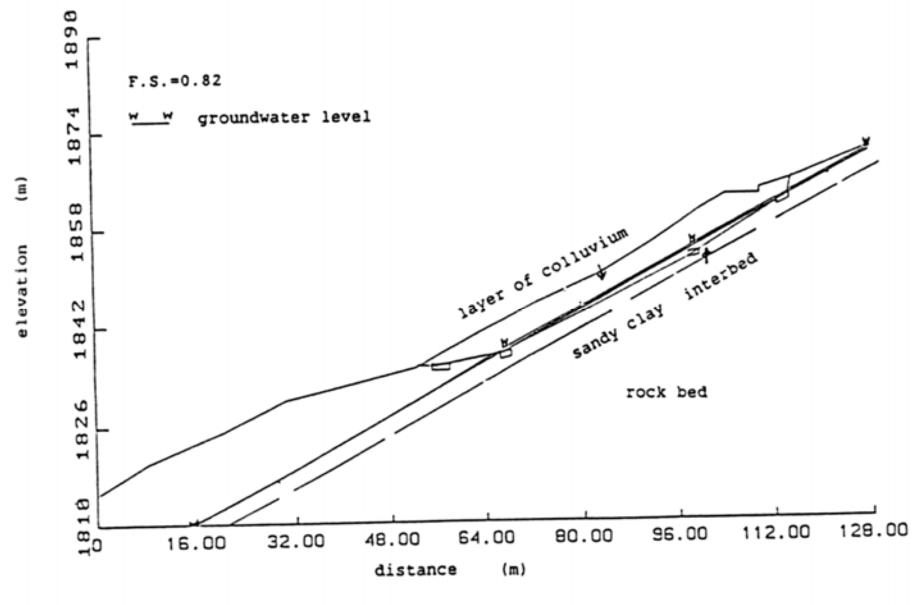

Figure 9. Result of slope satability analysis of section A - A

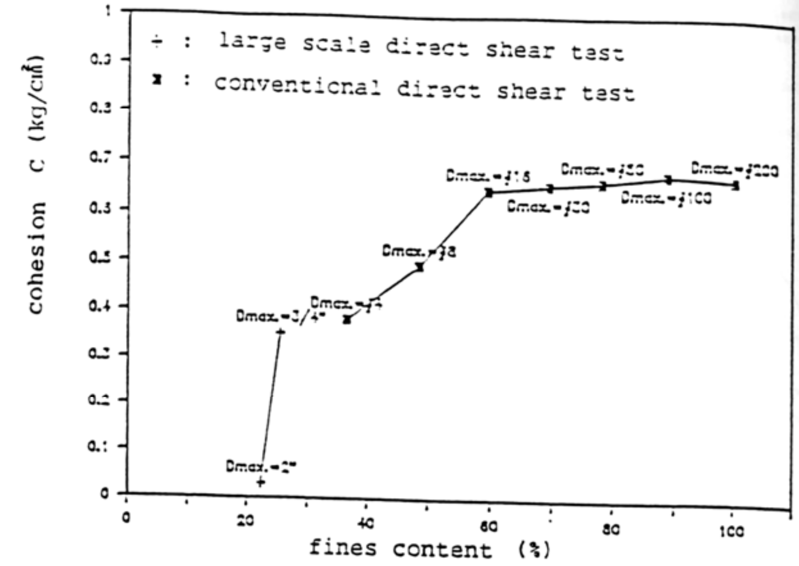

Figure 10. Result of direct shear test of colluvium - The relationship of fines content (f) vs. cohesion (c)

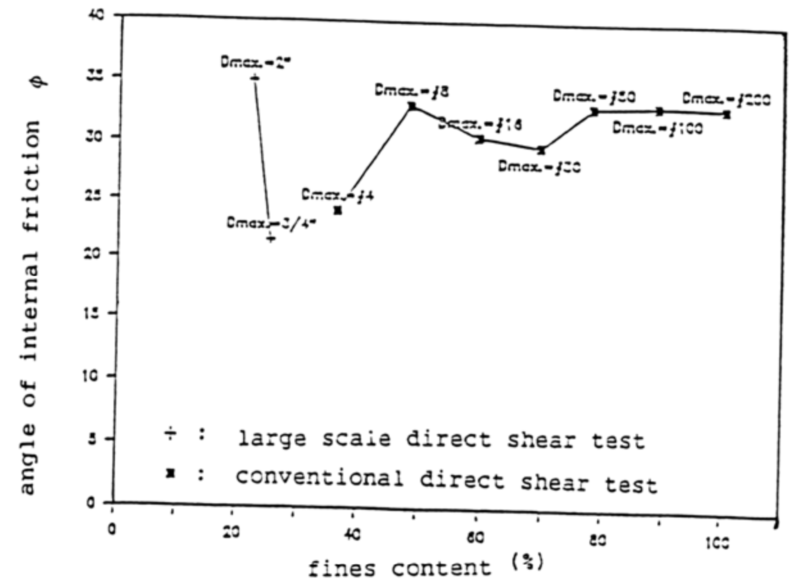

Figure 11. Result of direct shear test of colluvium - The relationship of fines content (f) vs. angle of internal friction (φ)