CHAPTER VI

GEOTECHNICAL INVESTIGATION

The geotechnical investigation is one of the main and decisive part of landslide study, especially, in the area where natural landslides exist. The investigation is done by diagnosing the factors responsible for the movement and determining the appropriate corrective measures prevent or minimize further movement. If the failure is unavoidable, the study will suggest the alternative communication routes that are less likely to slide.

The investigations were carried out in two scales namely regional geotechnical investigation along Prachinburi-Khao Yai area and local geotechnical investigation of the area of embankment failures. The work includes topographic, geotechnical and engineering geological mapping, drilling, test trenches and pits, standard penetration test and samples collecting. The purposes of the investigation are as follow.

a) To identify the weaker formations that are likely to be involved in mass movement.

b) To identify the stronger formations that offer significant resistance or that might limit the extent of the zone of movement or provide support for retaining structures.

c) To locate the aquifers and to define groundwater levels and pressures.

d) To obtain the quantitative value of the physical properties of the materials for use in analyses of stability.

6.1 Regional Investigation along the Prachinburi-Khao Yai Area.

Regional geotechnical investigation along Prachinburi-Khao Yai area was performed. In order to know the physical and some engineering properties of exposed rocks and of the upper 0.5 meter of soil around the study area. The result is presented as a geotechnical map (Plate 6.1).

According to Fookes (1969), a geotechnical map can be prepared by mapping in unit base on one of the engineering properties or set of properties as follows:

i) By mapping units in descriptive geologic terms with weight being given to information of engineering interest.

ii) By mapping in terms of index properties, e.g. grain size, consistency.

iii) By mapping in terms of design parameters, e.g. permeability, strength.

6.1.1 Method of geotechnical mapping.

Regional geotechnical mapping was performed using the general geology plus Fookes's (1969) second criteria, i.e. the grain size and consistency. The consequence of mapping are as follows:

i) Air-photographic interpretation of an approximate scale 1:50,000

ii) Field investigations including standard field visits and soil boring by hand-augers and sampling within each of the main geomorphological features.

iii) Laboratory investigations including some soil tests e.g. grain size analysis, Atterberg limits test, and rock mechanics tests e.g. point-load strength test.

iv) Construction of rock and soil unit map.

6.1.2 The classification and nomenclature of rock and soil units.

The rocks and soils in the study area can be divided into 3 groups composing totally of 11 units. The units are shown in a geotechnical map of the area already presented in Plate 6.1. The 3 rock/soil groups with their subunits are listed as follows:

6.1.2.1 Surficial deposits.: The deposits comprised of marine, fluvial sediments and transported soils occurs in the middle and southern portion of the study area. The group consists of 6 soil units as list below.

a) Clay soils unit (Qa) of dark gray to black clay occupied in flat surface.

b) Non-plastic soils (VL; Qt_1) of brown to yellowish brown silty fine sand, 50-65% fine sand, 30-50% silt and clay, depth to bedrock is usually 7-15 meters.

c) Non-plastic to slightly plastic soil (VL-SL; Qt_2) of brown to pale brown, grayish brown clayey silty fine sand and silty clayey fine sand, 40-50% fine sand, 35-60% silt and clay, PI 10-13, depth to bedrock is usually 5-15 meters.

d) Slightly to medium plastic soil (SL-M; Qt_3) of brown to grayish brown silty clay or clayey fine sand, PI 4-22, depth to bedrock is 7 - 20 meters.

e) Undifferentiated alluvium (Qt_4) consisting of silty and sandy soils.

f) Colluvial deposit (Qt_5) of grayish white soils consisting of a lot of large rock fragments and boulders in gravelly clayey fine sand matrix. The boulders and cobbles commonly comprise 25%, subangular to subround, moderately to slightly weathered while the matrix is loose to medium grayish white, gravelly clayey fine sand, slightly plastic (PI= 8) with some gravel up to 10%.

The thickness of the deposit is about 12 meters. The existing natural landslides are found at the middle portion of the colluvial mass.

6.1.2.2 Duricrust deposits(L).: Duricrust in this area is lateritic soil and occupied in middle and high terraces. This lateritic soil can be divided into 2 units as follows:

a) Duricrust in middle terrace.: The unit is characterized by clayey gravelly sand with 35-40% gravel and about 45% sand, slightly plastic laterites.

b) <u>Duricrust in high terrace</u>.: This unit of lateritic soils occurs extensively . It is characterized by clayey sandy gravel or clayey gravelly sand with 35-55% gravel, slightly to medium plastic laterite. The thickness is usually over 1.50 m., up to 9 meters locally.

6.1.2.3 <u>Rock units</u>.: These rock units locates in the mountainous area of Khao Yai National Park. This area is in the northern portion of the study area. The rocks are divided into 3 units as follows:

a) <u>Sandstone unit</u> of white-yellowish brown, thick bedded sandstone, moderately to well cement, moderately strong rocks (50-60 MN/m^2).

b) <u>Mudstone and Siltstone unit</u> of reddish brown, purplish red, stiff soil to moderately weak rocks locally interbedded with strong to very strong rocks (100-250 MN/m^2) while the rock in the lower part of this unit is highly to completely weathered basal conglomerate.

c) <u>Volcanic rock unit</u> of thick layers, more than 12 meters, of slightly to completely weathered rhyolite, andesite, tuff and agglomerate, moderately strong to strong rocks (60-175 MN/m^2).

6.2 <u>Local Geotechnical Investigation of the Study Area</u>.

A detailed geotechnical investigation was carried out for the last two failures in 1983 and 1985-1986. The works are as follows:

6.2.1 Surface investigation.

6.2.1.1 Detailed topographic map.: To obtain detailed topography of the study area, a contour mapping on scale 1:200 were carried out. The mapped area is 200 by 350 square meters. The surveying points were located using a control point method. A "Wild T 16" theodolite were used in this topographic mapping. The contour interval is 1 meter while the boundary, height, major scarps, cracks, and drainage channels were mapped together with the location and elevation of the water seepages.

In this study, the influence of surface water on the stability of embankment slope was interpreted. The topographic map was also used as a base map for the detailed engineering geological map and to study the landslide movement.

6.2.1.2 Profiles.: The profiles of the slide areas were prepared following the lines of steepest slope parallel to the direction of movement. Four profiles were constructed and used in the stability analysis.

6.2.1.3 Engineering geologic map.: From the data obtained in the geologic field observation and from the surface and subsurface hydrological investigation, the detailed engineering geologic maps of scale 1:200 was constructed as shown in Figure 6.1 and Plate 6.2.

6.2.2 Subsurface investigation.

6.2.2.1 Rotary drilling.: As the core recovery in colluvium is generally poor, often with only the rock fragments being retrieved while the flushing medium generally washes away the intervening soils, a rotary drilling, using large diameter triple tube core barrels with retracting inner barrel and with either air-foam flushing or carefully controlled water flushing which can produce high quality samples of residual soils and colluvium was suggested by Phillipson and Chipp (1982). The method was thus followed in the present study for 9 drilled holes using a 4 inch-diameter drag bit trailer-mounted power auger. The location of the drilled holes is shown in Figure 6.2 and Plate 6.2.

The Standard Penetration Tests were also performed in drilled holes at every 1 meter interval. Samples collected by the split-spoon sampler were kept in cans for later natural moisture content determination. The description of soils were made through the depth. The procedures of rotary drilling are as follows:

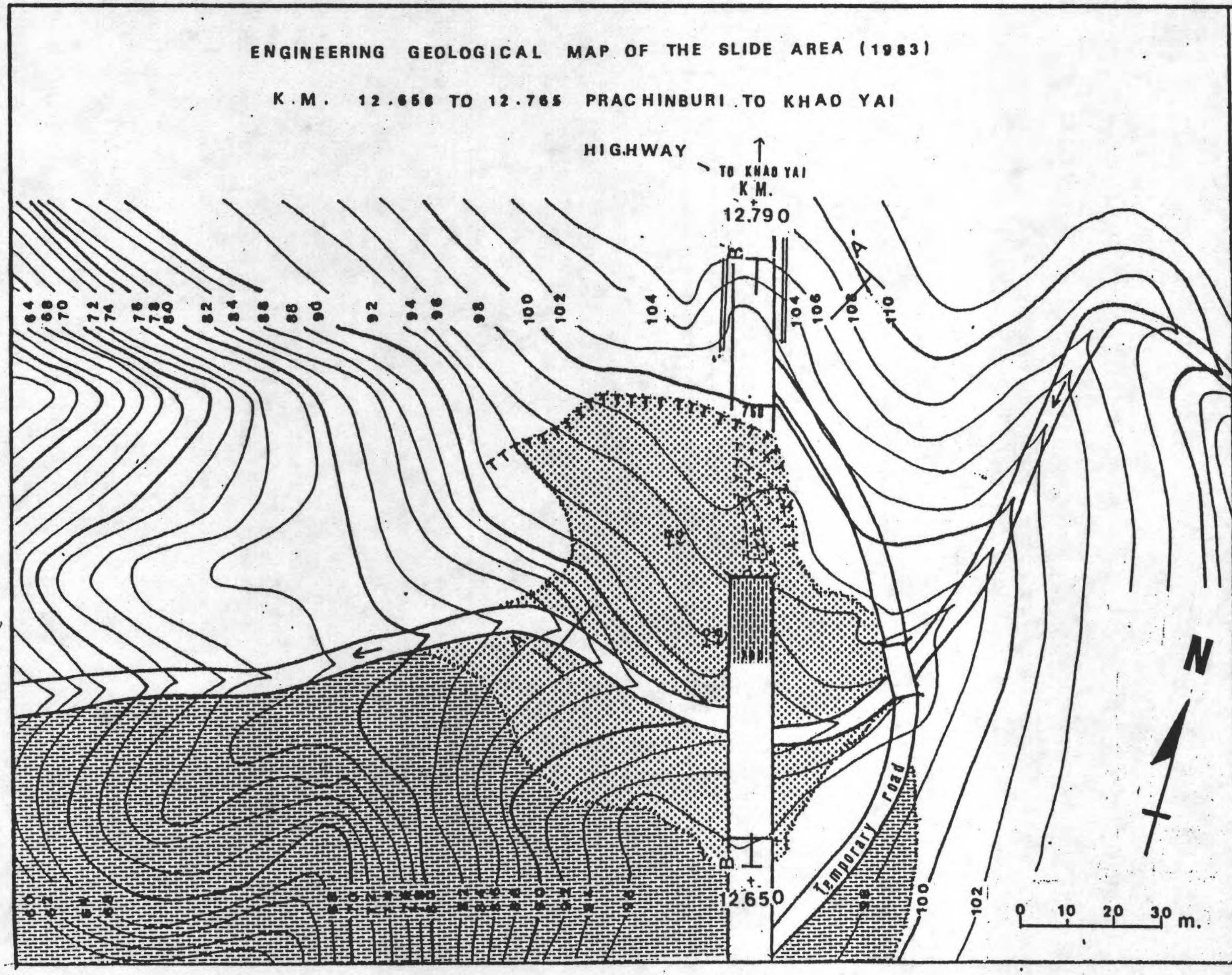
i) No flushing medium was used in order to clearly observe the ground water condition.

ii) The Standard Penetration Test was performed and soil samples were collected with the split-spoon sampler for examination and natural moisture-content determination.

iii) The groundwater level and type of aquifer at first encountered were noted.

iv) The piezometers were installed in the holes.

The boring-log data for failure in 1983 and 1985-1986 were shown in Appendix A.



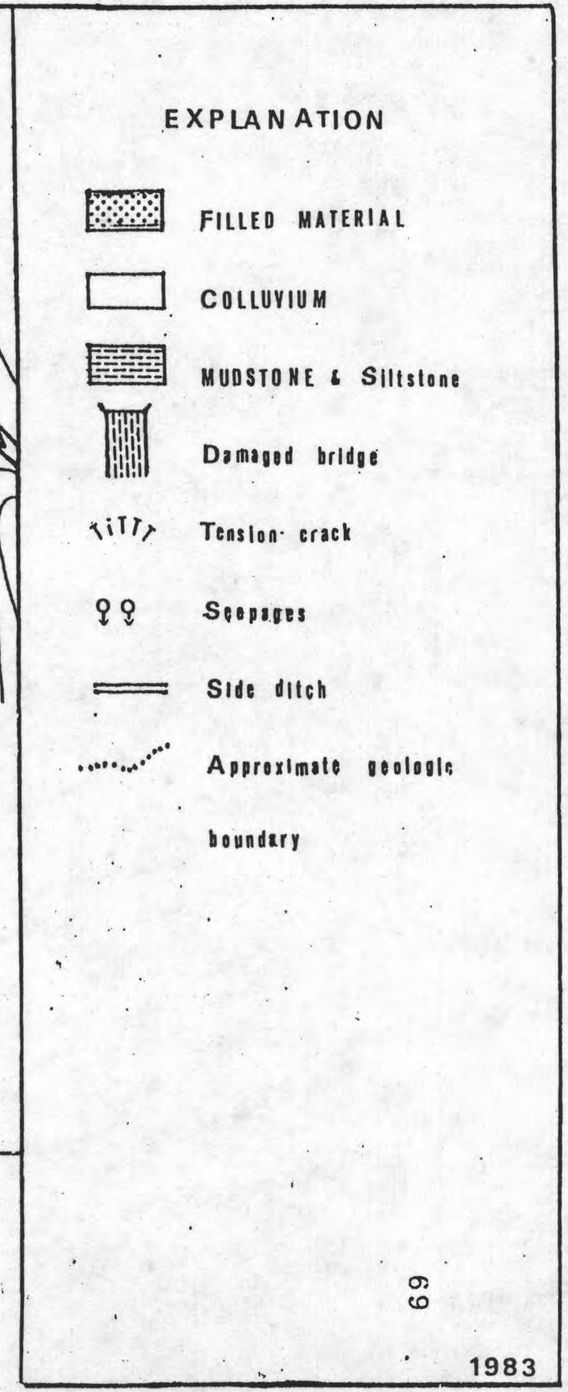


Figure 6.1 Engineering geological map of the slide area (1983).

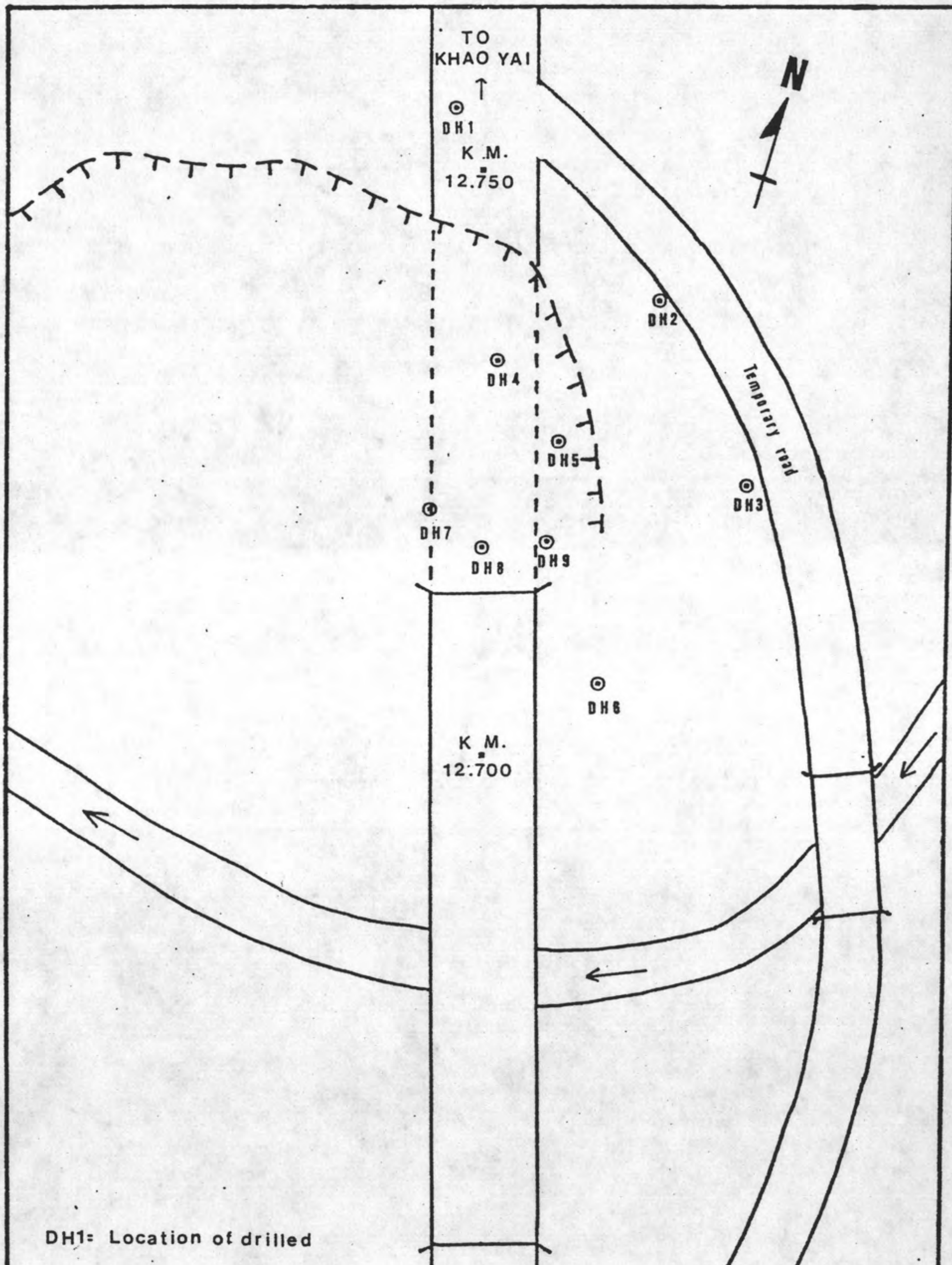


Figure 6.2 Location of 9 drilled holes (for subsurface investigation of failure in 1983.)

6.2.2.2 Simple sounding penetration test.: This portable dynamic penetration test is performed in order to provide an indication of the comparative density of soil layers. The equipment consists of a 2.50 cm.-diameter solid cone driven into the soils at the ground surface by a dynamic load from which a 5 kgs. weight is dropped from a height of 50 cm. The number of blows for 10 cm. of penetration is counted as the value of number of blows or N_C. It can penetrate the soils with the maximum depth of 5 meters. The equipment set up is shown in Figure 6.3.

During the heavy rain period in August 1985 when the tension cracks were first noticed on the embankment, the simple sounding test was performed over the area of landslide (Figure 6.4). The location of test sites and the results of sounding diagram in the embankment is shown in Plate 6.2 and in Appendix B respectively.

The results of simple sounding penetration test was summarized for each group of soils materials as follows:

a) Soil embankment material.: The soil is usually soft with a high water content. The N_C value is usually less than 6.

b) Gravel drain.: This layer underlies the soil embankment material and is found at the depth of 1.50 to 2.50 meters below the ground surface. The thickness varies from 1 to 1.50 meter with the N_C value ranges from 10 to 30.

It is unfortunate that this layer was not installed at the proper location proposed in the design.

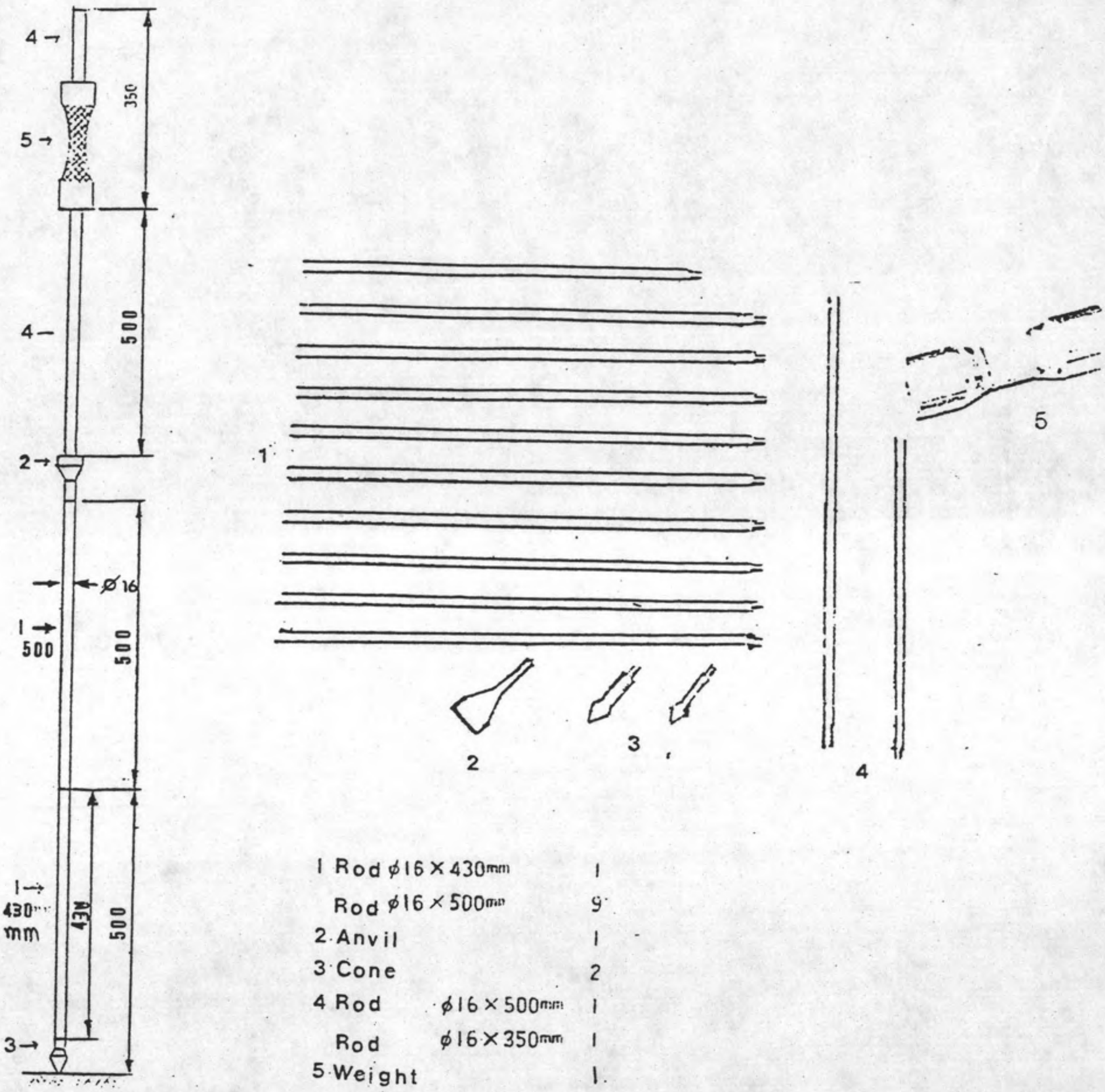


Figure 6.3 Simple sounding penetration setup.

Figure 6.4 Examination of soil layers by simple sounding penetration test in the landslide area (August 1985).

c) Groundwater surface.: The groundwater surface was located within the gravel drain layer, and found at the depth of about 2.5-3 meters below ground surface. This groundwater surface was determined from the trace of water at the rods of the equipment.

6.2.2.3 Test pits.: Six test pits with the depth of 1 to 4 meters were dug both into the filled materials and colluvial mass. These pits were used to observe the vertical arrangement of the texture and structural characters of soils. The undisturbed block samples and disturbed bag samples for laboratory test were also collected simultaneously.

6.2.3 The interpretation results of local geotechnical investigation.

The data gathered from subsurface investigated were interpreted as follows:

Filled materials.: In the study area of embankment failure, the thickness of this soil varies from 3 to 6 meters and is underlain by colluvium. The filled materials can be divided into 3 groups as follows:

- Upper soil.: For failure in 1983 filled material is loose reddish brown clayey sand. For failure in 1985/1986 the filled material is loose to medium yellowish brown silty sand. The thickness of this soil varies from 2 to 3.5 meters.

- Lower soil.: The filled material in this layer derives from the colluvial loose to medium clayey sand around the area. The thickness varies from 1 to 2.5 meters. The soil characteristic is thus similar to the colluvial material.

- Gravel drain.: In the second remedial work after the 1983 slope failure a gravel drained was installed underlying the upper soil layer of filled material. As stated previously this drain layer was not installed at the location specified in design. The thickness of this gravel drain varies from 1 to 1.50 meters.

Colluvial soil.: The colluvial soil is loose to medium clayey sand with a lot of rock fragments and very large boulders. In the landslide area the thickness of colluvium varies from 4 to 12 meters.

Shear zone soil.: Shear Zone was observed in bore holes No. DH_6, DH_{10} and DH_{11}at the base of the colluvium. The shear zone soil is very stiff clay with the thickness less than 1.50 meter.

Mudstone and siltstone bedrocks.: The bedrocks are characterized as hard to very hard, impervious materials.

The orientation of existing weathering profile or the interface between colluvium and residual soil is generally the same as the mudstone beds.

From the study of the failure in 1983, the ground water surface was often found beneath the upper layer of filled material. Although the investigation was carried out in the dry period, the confined aquifers were found both in the sliding mass and colluvial mass.

For the failure in 1985-1986, the ground water level was found in the gravel drain layer at 2 to 3 meters below the ground surface.

The shear zone soil or unsuitable materials of the failure surface had never been stripped off since the first remedial construction, thus any failure would have been occurred again and again along this existing failure surface.

6.2.4 In-situ shear strength test of soils:

6.2.4.1 Standard Penetration Test: This test was performed in the bore holes at every 1 meter. The test is to drive down a split spoon sampler by mean of a 140-pound weight free-falling 30 inches on to a rod with the sampler screwed tight on its end. The split spoon sampler is an open-ended cylinder which splits longitudinally into two halves. These two halves are held together by a cutting shoe at the lower end.

The number of hammer blows for 6 inches of penetration is recorded. The total number of blows required to drive the second and third 6-inch penetration represented number of blows per foot or N-values. The Standard penetration equipments and testing results in the bore holes are shown in Figure 6.5 and Appendix A respectively.

Based on N-value of each layers, the soils are classified according to Terzaghi and Peck (1948) as loose to hard as follows:

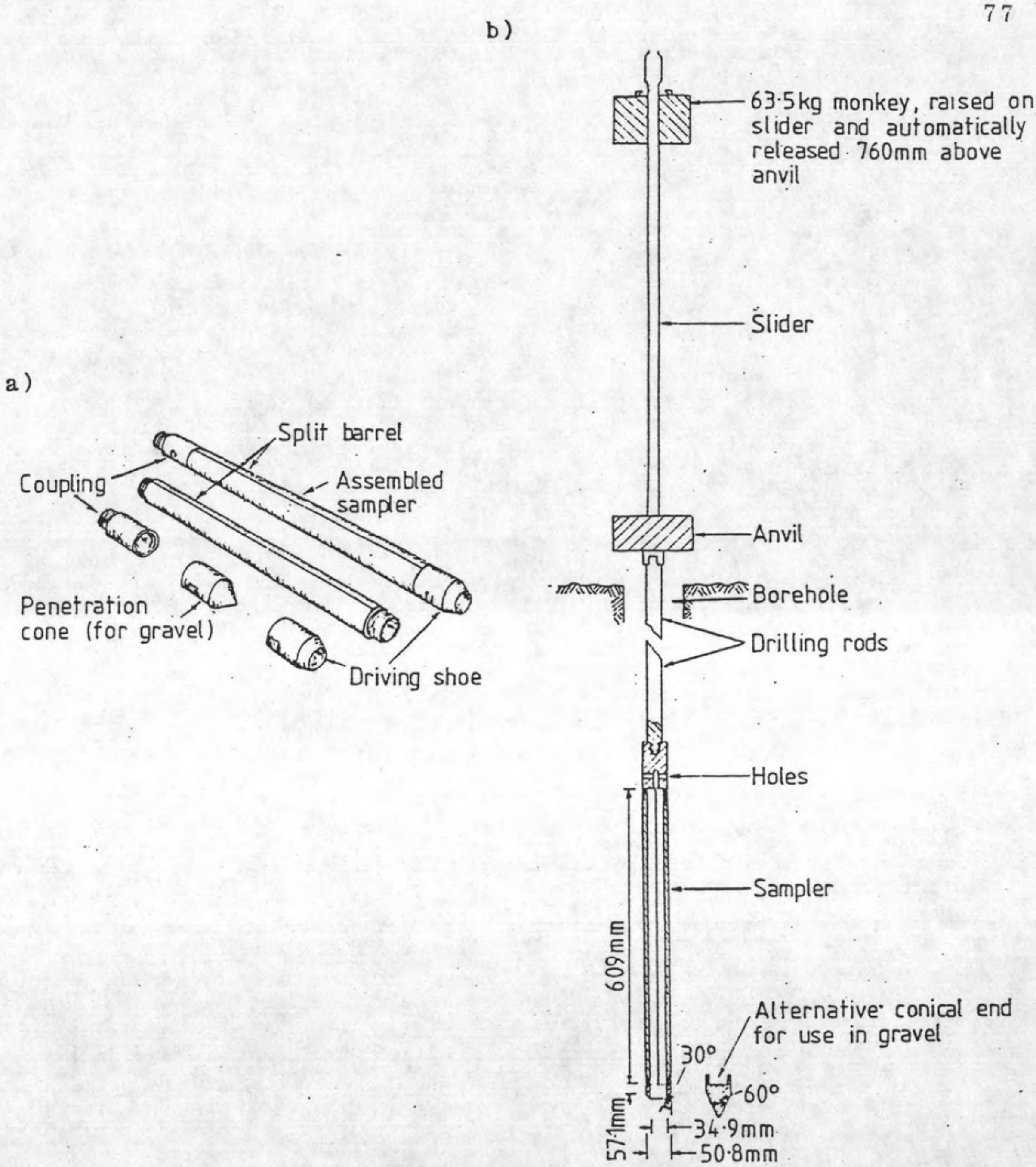


Figure 6.5 Standard Penetration Test equipment.

a) Split spoon sampler

b) Schematic arrangement of standard penetration test equipment in borehole (From Carter, 1983).

a) <u>1983-Filled material</u>.: This soil is loose sand with N-value ranging from 5 - 9, averaging 6.

b) <u>1985/1986-Filled material</u>.: The soil is loose to medium sand with N-value ranging from 5 - 12.

c) <u>Colluvial soil</u>.: It is very loose to medium sand with the N-value ranging from 4 - 16, averaging 11.

d) <u>Shear zone soil</u> .: The soil in the shear zone is very stiff soil with the N-value ranging from 20 - 25.

e) <u>Mudstone and Siltstone bedrocks</u>.: They are hard to very hard with N-value greater than 50.

6.2.5 <u>Soil sampling methods</u>:

The extremely heterogeneous nature of the colluvium makes the sampling and testing very difficult. The slickensides at the shear zone soil upon which movement had taken place in the past are hard to locate and the soil sample there is to be collected difficult. If the soil samples are collected from elsewhere, where the strength is higher than that in the zone of slickenside, the analysed strength of soil sample and factor of safety of the slope can be simply overestimate.

Three types of soil samples were taken, i.e. undisturbed box samples, disturbed and driven samples. The samples were taken at the test pits, road cut slopes, and bore holes. The locations and detailed description were recorded in the field.

6.2.5.1 Sampling and type of samples.:

a) Disturbed samples.: This type of sampling was performed in the zone of filled materials and colluvium. The organic contained top soil was first stripped off from then the soil samples at the desired depth were collected and kept in water proof sample bags. The bags were designated and tied. The soil samples were for the classification tests while a portion of samples was also kept in cans for moisture content determination.

b) Driven samples.: The 35 mm. diameter sample taken by the split spoon sampler are obtained in conjunction with the Standard Penetration Test. The soils samples were kept in double plastic bags a portion being kept in can. The samples in plastic bags were for the textural and physical determination, the one in can for natural moisture content determination.

c) Undisturbed box samples.: This type of sampling was performed in the zone of filled materials, colluvium and shear zone soil . In the test pits and cut slopes, the 15 cm. cubic blocks of samples were trimmed in situ. A wooden box of slightly larger size was used to cover the block sample. The space between the soil sample and the wooden box was filled in situ with paraffin wax (Figure 6.6). Then, the sample was removed and transported to the laboratory. The samples were for the strength tests and classification tests.

Figure 6.6 Collection of undisturbed box sample of sheare zone soil.