FEASIBILITY OF A PERMANENT BUND IN THE PONNANI KOLES OF KERALA

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PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology in Agricultural Engineering

Faculty of Agricultural Engineering
KERALA AGRICULTURAL UNIVERSITY

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TAVANUR - 679 573
MALAPPURAM

1996

DECLARATION

We hereby declare that this project report entitled **"FEASIBILITY OF A PERMANENT BUND IN THE PONNANI KOLES OF KERALA"** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, associateship, fellowship, or other similar title of any other University or Society.

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CERTIFICATE

Certified that this project report, entitled **"FEASIBILITY OF A PERMANENT BUND IN THE PONNANI KOLES OF KERALA"** is a record of project work done jointly by Mr. Abdul Sathar, M., Miss Karen Mary Nigli and Miss Sajeena, S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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ACKNOWLEDGEMENT

We are very much indebted to and express our deepest sense of gratitude to our guide, Smt. Mary Regina, F., Assistant Professor, Department of Irrigation and Drainage Engineering, for her valuable advice, guidance, sincere and constant encouragement throughout our work.

We are also thankful to Dr. John Thomas, Dean, KCAET, Tavanur, Dr. C.P. Muhammad, Professor and Head of Department of Farm, Power and Machinery who extended their help and support during the course of this study.

We also express our heartfelt thanks to Dr. Unnikrishnan and Er. Xavier of KLDC, Trichur, for all the help rendered during the early stages of this work.

We gratefully acknowledge the help rendered by Sri. Kochappan, Assistant Director, Smt. Sheeja and Sri. Aravindakshan of KERI, Trichur without whose help completion of this work would have been impossible.

We are also grateful to Sri. V.M. Abdul Hakkim, Assistant Professor, Kerala Agricultural University, Vellanikkara and Prof. Stephen J. Nigli, for the help rendered during various stages of this work.

We sincerely express our indebtedness to all our student friends at KCAET who have helped us, and, especially to Suresh Babu, M.S., Aji, R. and Anvur, V.A.

A word of thanks is also due to M/s Peagles, Mannuthy for their neat typing and prompt service during the preparation of the final report.

In this endeavour, we recollect the warm blessings and support of our loving parents who have been guiding us throughout.

And above all, we humbly bow our head before God for his blessings.

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SYMBOLS AND ABBREVIATIONS USED

cm	-	centimetre
cm^2	-	square centimetres
cm/sec	-	centimetre per second
cu.ft.	-	cubic feet
etc.	-	excetra
Fig.	-	figure
gm	-	gram
g/cc	-	grams per cubic centimetres
g/cm^3	-	grams per cubic centimetres
ha	-	hectares
hrs/day	-	hours per day
i.e.	-	that is
kg	-	kilogram
kg/cm^2	-	kilogram per square centimetres
kg/cm^3	-	kilogram per cubic centimetres
kg/ha	-	kilogram per hectare
KERI	-	Kerala Engineering Research Institute
KLDC	-	Kerala Land Development Corporation
km/hr	-	kilometre per hour
lb	-	pounds
log	-	logarithm
m	-	metre
ml	-	millilitre

mm - millimetre

mm/day - millimetre per day

mm/yr - millimetre per year

MSL - mean sea level

NE - North East

sec - second

tan - tangent

° - degrees

°C - degree centigrade

" - inches

% - percentage

INTRODUCTION

The Agricultural Scenario in Kerala regarding the yield of rice is quite dismal which is still below two tonnes per hectare. The average yield of rice during the period 1980-1989 was 1637 kg/ha for Kharif season and 1970 kg/ha for Rabi season. So a rapid increase in rice yield is warranted to stabilize the food security base of the state.

Due to a wide diversity in agro-ecological conditions, a large variation in the performance of the crop exists across different zones in the state. One of these, the 'Kole lands', form the rice granary of Thrissur and Malappuram districts and comprise of a unique agro-ecologic zone.

The Kole land is a low lying tract that lie parallel and adjacent to the Arabian sea at a depth of 0.5-2 m from mean sea level. This area has no natural provision for drainage into the sea and remain submerged for about 6 months right from the start of the south west monsoons.

While the average productivity of rice in the state is less than two tonnes per ha; Kole lands yield 4 to 5 tonnes per ha and 7 or 8 tonnes per ha are not uncommon. The high inherent fertility of the soil of the Kole land can produce bumper yields under favourable conditions. 'Kole' is a malayalam word which indicates a bumper yield or high returns but for the damaging floods.

The Kole lands covering an area of 13632 ha. are distributed over Thrissur and Malappuram districts and extends from the northern bank of the Chalakudy river in the south to the southern bank of the Bharathapuzha river in the north of Kerala. This tract was formerly a lagoon formed by the recession of the sea centuries back. The sand bar when formed isolated a shallow portion of the sea along the western periphery of the land. This shallow lagoon got gradually filled up with the eroded material from the higher land washed down during the rains making the lagoons more shallow. These areas were then bunded up by enterprising cultivators and then dewatered and cultivated. The cultivation was done only during the summer months. But an early south west monsoon did a lot of damage to the crops. As a result, the crop had the risk of flood damage and success was often a chance. Also during summer there will not be sufficient water for the crop to grow till harvest. Thus cultivation of only one crop from January to April is possible as the fields remain flooded for the major part of the year.

The majority of farmers are small and marginal, with the size of holdings ranging from 0.2 to 0.7 ha. The temporary bunds have to be repaired every year to be above the flood level of NE monsoon, which require investment. These temporary bunds are liable to be breached which add to the cultivation expenses of the farmers.

The problems of the Kole lands are many, the most important being submergence and lack of drainage. The kole lands being situated below sea level is the drainage basin of several streams. The accumulated drainage practically stagnates as the flow towards the sea is very slow. The water then spreads out in the entire Kole area and submerge the fields. These floods often spoil the bunds and damage the crop if heavy rains occur during the crop season. The huge annual expenditure required for providing temporary mattoms or bunds has been found to be very risky as the mottoms get breached and the area gets flooded early. Construction of permanent bunds having 2-3 m. top width around the padasekharam was proposed.

On construction of permanent bunds an additional crop (Mundakan) can also be easily cultivated in the whole area since the permanent bund separates the field from the river channel. The permanent bunds can provide means for transportation of manure, fertilizers and produce and at the some time making the fields accessible to farm machinery. Some areas have already been enclosed with permanent bunds with the assistance of the Minor Irrigation Department facilitating the cultivation of an additional crop during the usual mundakan season (September-December). But it has been found that the bund breaches after every cropping season due to excessive floods.

A permanent bund running from Naranipuzha to Kummipalam near Marancheri of Ponnani kole was investigated. It was found that the bund breached every year when flood water reached its maximum level. The bund had to be repaired every year before the main cropping season commenced. The repairs were very costly and resulted in financial strains on the governmental organisation involved in the construction and maintenance of these bunds. Hence a feasibility study on the design of permanent bunds to save the kole land was highly significant and was attempted.

The specific objectives of this study were:

1. To analyse the characteristics and mechanics of soil in the problem area and to find factors responsible for bund stability/breaching, and

2. To develop modified design criteria for permanent bunds in the Kole area.

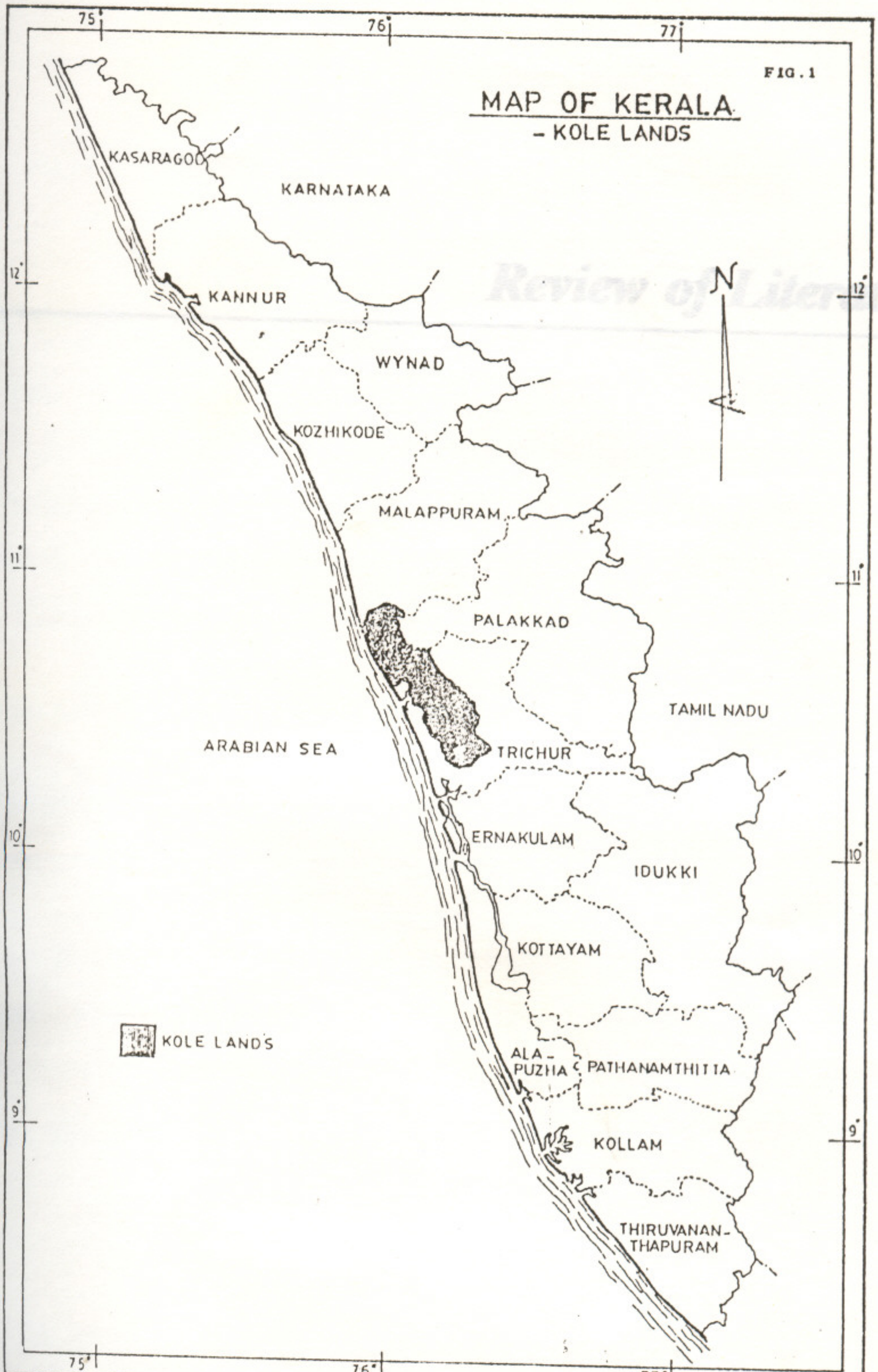


FIG 1. GEOGRAPHICAL DISTRIBUTION OF KOLE LANDS OF KERALA.

SOURCE: KOLE LANDS OF KERALA (1993).

REVIEW OF LITERATURE

The Kole land is generally known as the rice granary of Kerala due to its high productivity and soil fertility. However its submergence for most part of the year poses a lot of problems. The previous study is primarily based on the Ponnani koles and studies relevant to the topic are briefly reviewed in the foregoing sections.

2.1 Geographical distribution of the kole land

According to Geographical distribution, the kole lands come under Thrissur kole and Ponnani kole.

The Thrissur kole is distributed in Mukundapuram, Chavakkad and Thrissur taluks of Thrissur districts comprising an area of 10,187 ha. The Ponnani kole comprising an area of 7445 ha. is distributed in Chavakkad and Thalappally taluks of Thrissur district and Ponnani taluk of Malappuram district.

2.1.1 The Thrissur kole

The Thrissur kole functions as a flood basin for the Kechery and Karuvannur rivers. The accumulated flood waters have to find a long way to have an exit to the sea and hence water spreads out in the kole area and submerge the fields.

2.1.1.1 Characteristics and problems

The area south of the Karuvannur river is a low lying tract varying from 0.75 m below MSL to 2.5 m below MSL. Normally no cultivation is possible in the low lying areas during this period. Only Puncha crop is raised successfully in these kole areas. Cultivation of 'Viruppu' crop is impossible due to the heavy floods of South West monsoon. In some areas an additional crop known locally as Kadumkrishi is raised by dewatering the flood waters after protecting the field with bunds. These bunds will thus protect the kole fields extending in the Kadumkrishi areas.

The area on the northern side of the Karuvannur river is a stretch of low lying areas situated at 0.25 m. to 2.25 m. below MSL. There is a system of drainage-cum-irrigation channels spread over the entire area. During the South-West monsoon the area resembles a lake when the canals are flooded and flood waters flow over the entire rice fields. Puncha is the main crop in the area which is raised during the period from January to May in the absence of floods.

In certain areas an additional crop is taken during the period i.e. August/September to December/January. For raising these crops temporary earthen bunds reinforced with bamboo are put up every year around the padasekharams since permanent bunds were lacking.

2.1.1.2 Development programmes and studies

Vasudev (1969) conducted a feasibility study for the construction of permanent bunds and other improvements to the kole lands. He proposed to set up permanent bunds and to improve and widen canals with a view to prevent water logging of the cultivable areas.

KLDC (1976) prepared a project report on Thrissur kole lands for construction and rectification of regulators and also for widening and improving the canal system.

KLDC (1978) prepared a project report for overall development of Thrissur kole lands with the objective of taking an additional crop (Mundakan) and providing irrigation for summer crop in the kole and nearby normal rice fields. Works for proper drainage of water from the kole fields, renovation and construction of bunds, digging new canals and improving the existing canals etc. were envisaged in the project.

2.1.2 Ponnani kole

Ponnani kole is the drainage basin of several small streams that flow into the Kanjiramukku river. During the monsoons as the flood waters rise in the river channels and the flow towards the sea is very slow, the accumulated flood waters overflow and submerge the rice fields completely. The koles thus lie under water for major part of the year. Due to this condition, a few of the enterprising farmers bunded the fields from the river channels dewatered them and raised rice in summer months.

2.1.2.1 Characteristics and problems of the area

The main crop raised in the Ponnani kole is Punja from January to April. The cultivation of Viruppu (April-May to August-September) is practically impossible in these areas. Towards the close of the North East monsoon, the bunds separating the deep kole or river channel are repaired, water from the fields are pumped out into the deep kole or river channel and sowing or transplanting done by January for the Punja crop.

The main problem of the Ponnani kole lands is lack of drainage. The flood waters accumulated in kole lands have to find a long way to have an exit into the sea and hence water spreads out in the entire kole area and submerge the fields. The problem of floods can be solved by the construction of storage reservoirs at the upper reaches of rivers, construction of flood banks, channelisation of flood flows and cutting a direct outlet to the sea from the flood plains (Mangalabhanu, 1979). Lack of permanent bunds is another problem in the Ponnani koles. An additional crop during the usual mundakan season (September-December) can be cultivated. For this the bunds have to be repaired every year to be above the flood level of the North East monsoon. These repairs are a recurring financial strain.

In the Ponnani kole, there is no external source of irrigation water. it the crop is commenced late there will not be sufficient water in the deep kole area to be used for irrigation during the last phase of crop growth. Thus the crop may either be damaged or yield may be reduced substantially. On the peripheral lands of streams where perennial and annual crops are raised, some land owners pump out water for irrigation which increases the problem of water scarcity.

Another difficulty felt by the cultivators is sea water intrusion which impose severe fresh water shortage is summer. The deep kole is part of the Kanjiramukku river and is connected to the sea through Ponnani through the Veliyamcode gap. Hence the water in the deep kole gets saltish. Submergence during monsoon is beneficial as it makes the soil more fertile and aids in the leaching of acidity in the fields. To irrigate the crop the water available in the deeper areas i.e., water courses is let in either by gravity or pumping.

When more and more areas were reclaimed this water was found to be inadequate and not suitable due to salt intrusion. Hence a regulator known as the viyyam regulator was built by the government at the downstream end of the area. The purpose of the regulator was to retain water at a higher level and exclude salt water during summer so that more fresh water can be stored in the deep kole. When this built it was found necessary to raise the padasekharam also to a higher level. This caused extra difficulties to farmers. Hence what actually happens is that the viyyam regulator which can retain water at 0.75 metres above MSL cannot do it due to low level of bunds and protest by cultivators.

2.1.2.2 Development programmes and studies

Achan (1959) submitted a detailed report for the improvement of Ponnani kole. Improvements in drainage, provision of side bunds and facilities for irrigation were suggested. Four proposals were made viz. widening of the regulator at viyyam dam, deepening the deep kole, forming permanent bunds on both sides of the deep kole and construction of lift storage schemes. Jose (1966) proposed the deepening of kole canals later studies on the improvement to viyyam dam were also taken up and completed.

The Executive Engineer (Investigation), Thrissur (1974) suggested four lift storage schemes at Panthavoor, Thattanthodu, Othallur and Anjilikadavu. Supply of irrigation water by pumping from the Bharathapuzha were investigated. Possibility of raising two crops, draining the water from kole fields direct to Bharathapuzha and taking in water direct from Bharathapuzha was also suggested.

Mangalabhanu (1979) suggested that bunds adjacent to the deep kole have to be raised in order to prevent over flow into the fields during the NE monsoon and to supply sufficient water for irrigation during the fag end of Puncha crop period. Canalisation of water courses, setting up of lift irrigation schemes and pump houses and improvements to the viyyam regulator were also dealt with.

2.2 Earthen bunds or embankments

The main barrier access the valley and stream bed for the purpose of storage of water is usually an earthen bund. For smaller tanks the height of the bund may be of 3-5 metres whereas in bigger streams the height may go upto 10 metres.

Earthen bunds or embankments are mainly of the rolled-fill type where the bund is constructed by spreading the soil material in uniform layers and then compacted at optimum moisture content until maximum density is achieved.

The selection of design of such embankments for water control is predicted upon.

1. The foundation properties, that is stability, depth to impervious strata, relative permeability, and drainage conditions, and

2. The nature and availability of the construction materials.

An earthen embankment must be designed to be stable for any force conditions or combination of forces which may reasonably develop during the life time of the structure. The three critical conditions to be considered in the design of an earthen embankment are:

(i) development of the shearing stress within the embankment due to the weight of the fill. If the magnitude of the shearing stress exceeds the strength of the fill material sliding of the embankment slopes and displacement of large portions of the embankments may occur. The same conditions may occur in the foundation the displacement of which would have a detrimental effect on the stability of the embankment.

(ii) the development of differential settlement within the embankment or its foundation is caused by variation of materials, variation of the height of the embankment above the foundation or compression of the underlying strata. This condition may cause the foundation to crack through the embankment. These cracks could encourage concentration of normal seepage through the dam and subsequent failure by piping.

(iii) The development of seepage through the embankment and foundation. This condition may cause piping or progressive internal erosion to occur within the embankment or foundation. Another effect of seepage is the continuing softening and sloughing of the toe of the slope.

2.2.1 Standard designs for earthen embankments

Saturation at the toe will cause sloughing or serious reduction in the shear strength. It is therefore always desirable to include a toe drain in the design of homogeneous embankments. Likewise embankments formed on pervious foundation or constructed of materials which exhibit susceptibility to piping and cracking should always be protected by an adequate drainage system. A graded

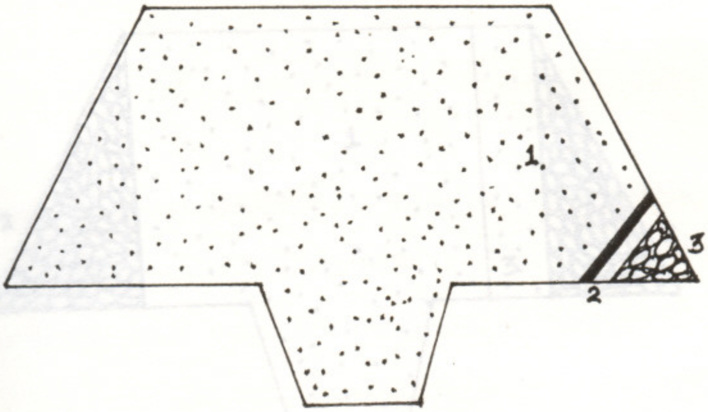


FIG 2(a)

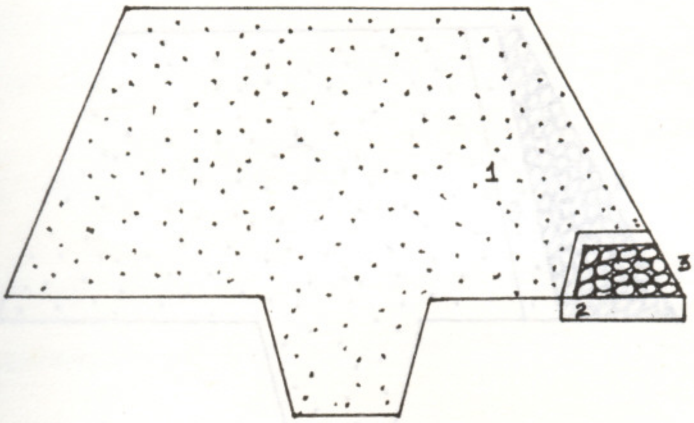


FIG 2(b)

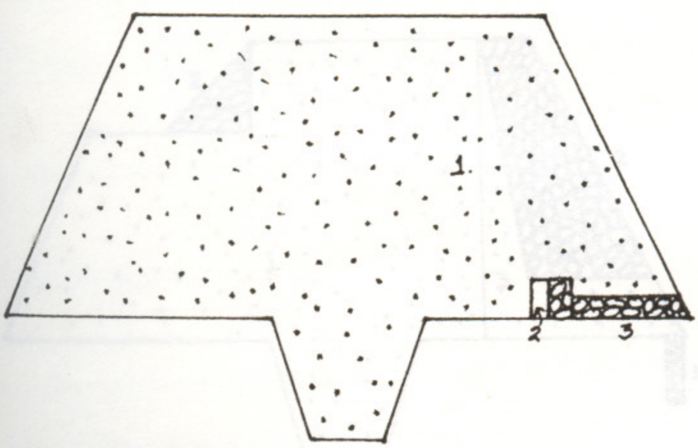


FIG 2(c)

1 - HOMOGENOUS FILL

2 - TRANSITION FILTER

3 - ROCK OR GRAVEL DRAIN

FIG 2. STANDARD DESIGNS FOR EARTHEN EMBANKMENTS (CONTD...

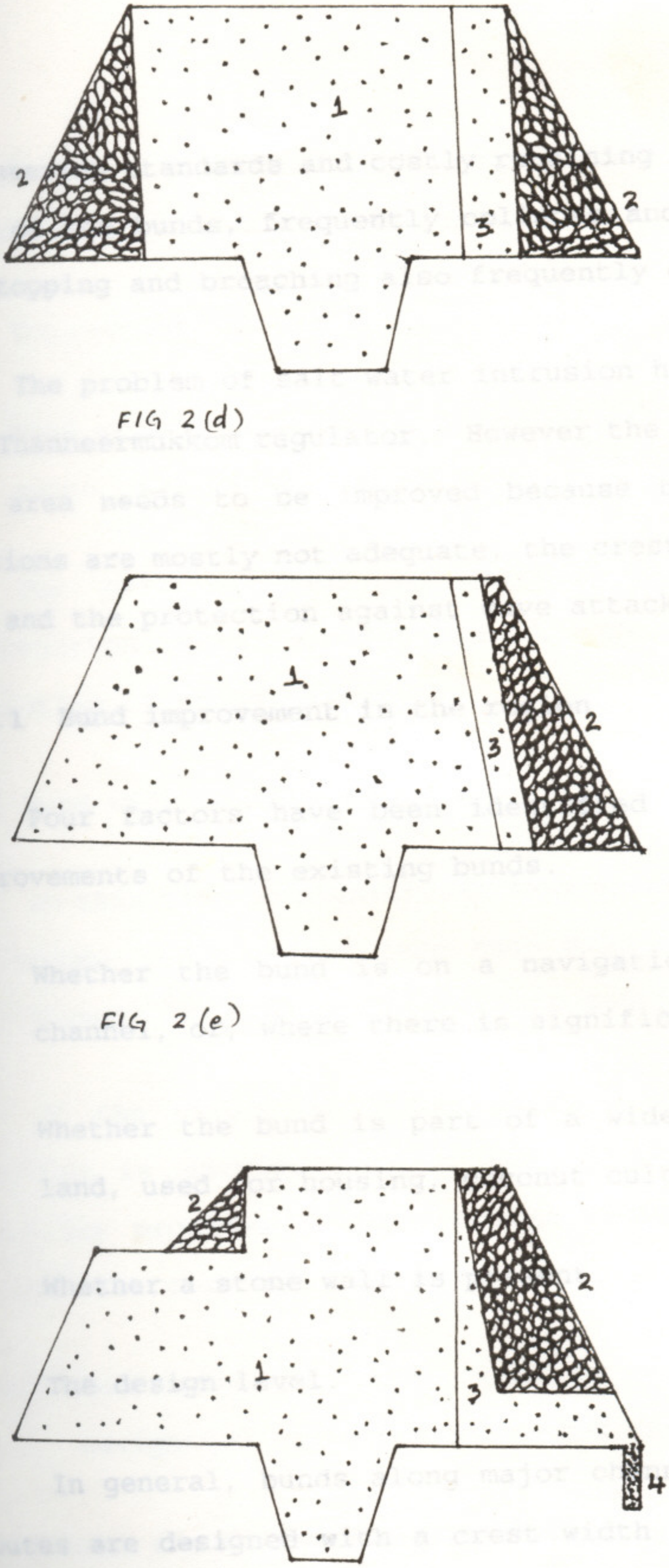


FIG 2(d)

FIG 2(e)

FIG 2(f)

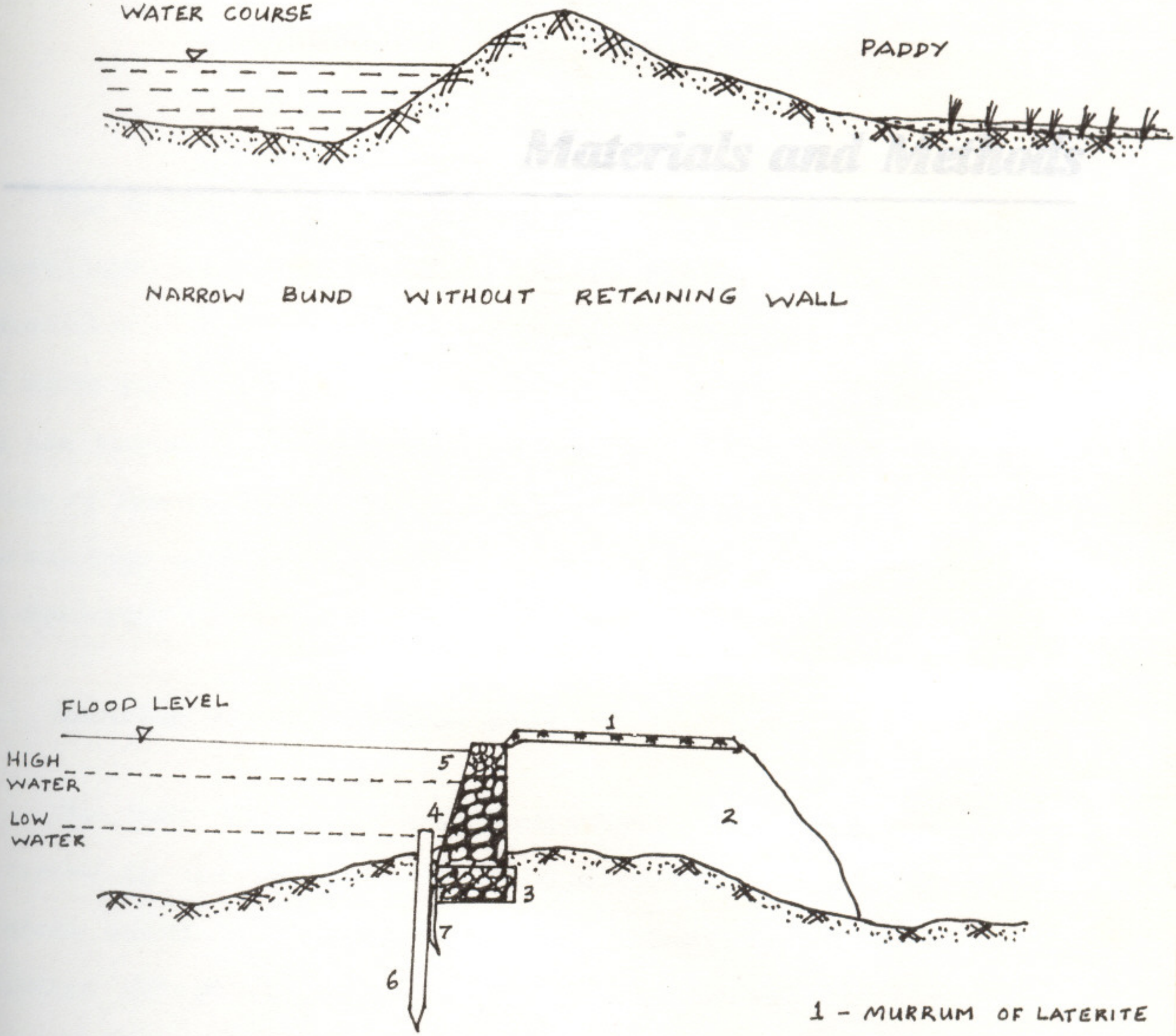
1 - RELATIVELY IMPERVIOUS ZONE

2 - COARSE PERVIOUS SHELL

3 - TRANSITION FILTER

4 - RELIEF WELL

FIG 2. STANDARD DESIGNS FOR EARTHEN EMBANKMENTS



1 - MURRUM OF LATERITE
2 - CORE OF FINE MATERIAL
3 - DRY ROCK RUBBLE
4 - DRY RUBBLE
5 - RUBBLE MASONRY
6 - COCONUT PALM TREE
7 - COCONUT TREE HALVES PLUS STRAW OR COCO PALM LEAVES.

FIG 3. TYPICAL CROSS SECTIONS OF EXISTING BUNDS IN KUTTANAD.

filter blanket can be placed between the fill and the drain as in the design illustrated in Fig.2(a), 2(b) and Fig.2(c).

The design shown in Fig.2(d) illustrates an embankment composed of large coarse grained pervious soil in the upstream and downstream side. The downstream pervious shell seems to lower the line of saturation in the same manner as does a toe drain. It increases the total shear resistance of the embankment. The upstream shell protects the embankment from failure due to stresses caused by rapid drawdown of the reservoir. The same can be applied in the designs illustrated in Fig.2(e) and 2(f).

2.3 Rice cultivation in Kuttanad region

Kuttanad is another area of coastal low land in Kerala with elevations ranging from 2 m below to 2.5 metres above mean sea level. The inhabitants have reclaimed and protected these low lands by constructing bunds to form paddy lands locally called padasekharams. Flood water enters Kuttanad from the upstream catchments during the monsoon. These floods overtop bunds, flood roads and homesteads.

The traditional paddy crop, the Punja starts at the end of the monsoon when the risk of flooding is over and salt intrusion is below its maximum. Recently a second rice crop is being planted on parts of the low land necessitating raising the bunds. The design of the bunds is not often upto engineering standards and costly retaining walls in front of many of the bunds, frequently collapse and need repairing. Overtopping and breaching also frequently occurs.

The problem of salt water intrusion has been solved by the Thanneermukkom regulator. However the existing bunds in the area needs to be improved because the current cross sections are mostly not adequate, the crests are usually too low and the protection against wave attack not sufficient.

2.3.1 Bund improvement in the region

Four factors have been identified in the design of improvements of the existing bunds.

1. Whether the bund is on a navigation route or major channel, or, where there is significant wave attack.

2. Whether the bund is part of a wider strip of raised land, used for housing, coconut cultivation etc.

3. Whether a stone wall is present.

4. The design level.

In general, bunds along major channels and navigation routes are designed with a crest width of 3 m and a free-board of 0.50 m and for the other water courses a crest width of 2 m and a freeboard of 0.30m is considered sufficient because no significant wave run up occurs here.

The designs for the different cases are described below:

(i) Bund with retaining wall on major channel or navigation route, and not at raised land.

The existing bund is replaced by a more stable construction with sloping banks, the bank protection consisting of stone masonry.

(ii) Bund with no retaining wall

In this case no significant wave attack is expected. If the height is increased less than 0.30 m then the bund is only brought upto an adequate cross section.

If the height is increased more than 0.30 m, stone pitching is carried out in the sloping banks to avoid stability problems. The openings between the stones are filled with clay and planted with grass.

(iii) Bund with retaining wall on a major channel or navigation route and at raised land.

Since a considerable part of the raised land is used for housing, close to the bank, it will be practically impossible to reshape the bank and bring it under a slope. In this case the stone wall is retained and a granular filter provided behind the wall. If the bund height has to be increased considerably, then dumping of rubble at the toe will be necessary to prevent slip of stone wall and bank.

MATERIALS AND METHODS

The stability of any permanent bund or embankment will depend upon the characteristics of the fill material and the foundation. To investigate reasons for frequent breaching of bunds and to propose design criteria for a permanent bund in the Ponnani kole it is necessary to conduct a thorough study of the soils of the fill material and foundation. The methodology adopted for conducting the above investigation is described in this chapter.

3.1 Location of experimental site

The bund running from Naranipuzha to Kummipalam is situated in the Veliyamcode village of Andathodu block of Ponnani taluk of the Ponnani kole. The Ponnani kole is situated 10°-40° to 10°-48° North Latitude and 75°-58° to 76°-04° East Longitude. To total area of Ponnani kole is 3445 ha.

3.2 Climate

The kole area has a moderate climate neither hot nor cold. Minimum temperature is about 18°C and maximum does not exceed 38°C. The atmosphere is humid being water logged and near the sea. The average rainfall in the district is

2,900 mm/year. The South West monsoon and the Noroth East monsoon merge to give a rainy season of over six months. There is practically little rain during December to April. Maximum rainfall occurs in June or July. More than ninety per cent of the rainfall occurs during the two monsoons.

3.3 Hydrological characteristics

Vettikadavuthodu, Anjoorthodu, Othallurthodu, Pallikarathodu, Panthavoorthodu, Mannorthodu and Pattannurthodu are the various tributaries that join the Kanjiramukku river, the main drainage basin in the Ponnani kole. The Kanjiramukku river directly falls into the sea at the Veliyamcode barrage which is closed during the summer. The Kanjiramukku river is also connected to the Kanoli canal and hence to the sea throughout the year (Refer Fig.4).

3.4 Geological features

The kole proper represents piedmont type deposit of valley fill, thickness of which may be about 10 to 15 meters. The valley fill material is of five to coarse of cassic including scree and talus material formed of gravel and sand of lateritic composition. Most of the areas which exhibit a lacustrine environment contain black carbonacious clay with lot of vegetable matter at various stages of decomposition.

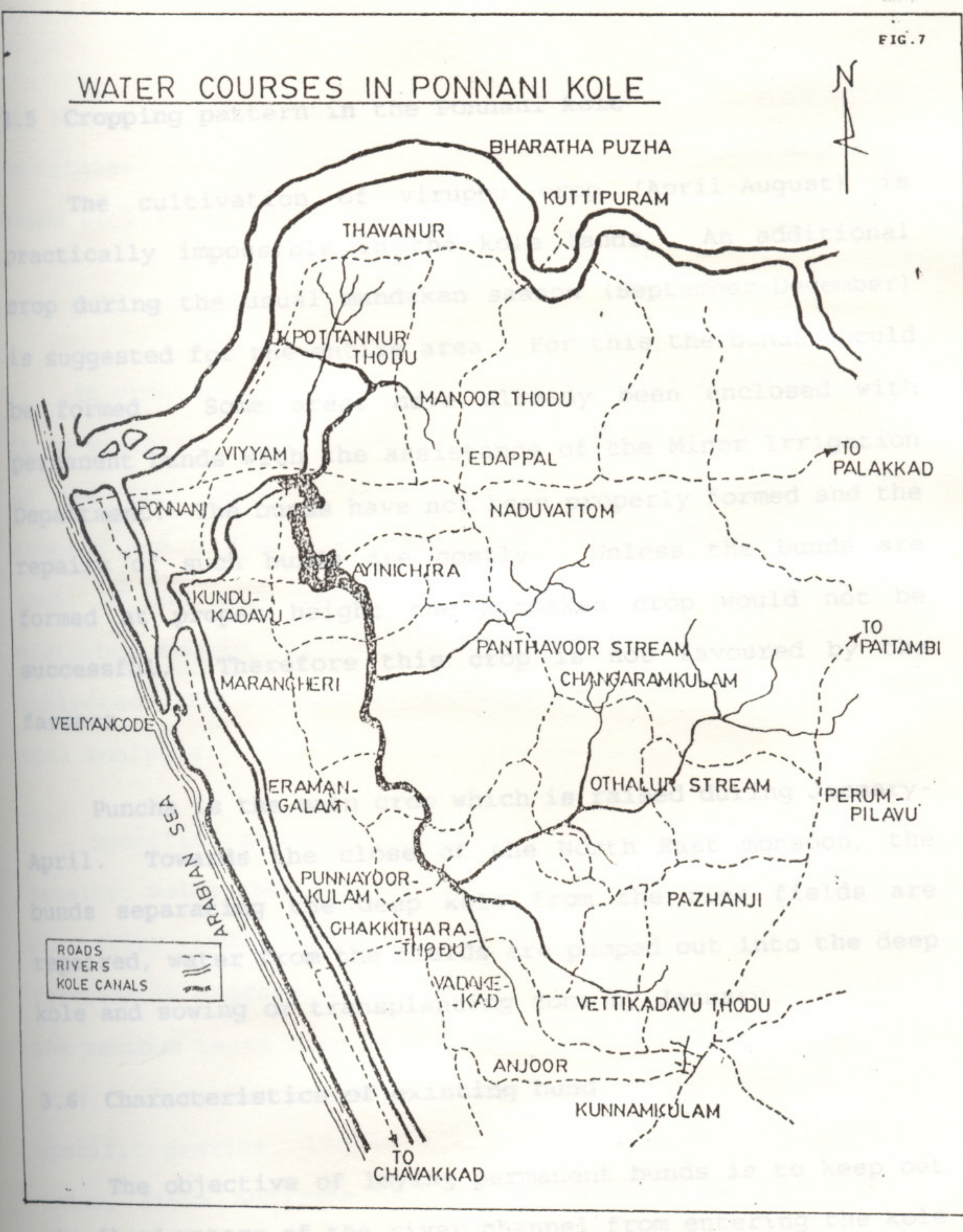


FIG 4. WATER COURSES IN THE PONNANI KOLE

SOURCE: KOLE LANDS OF KERALA (1993).

3.5 Cropping pattern in the Ponnani kole

The cultivation of viruppu crop (April-August) is practically impossible in the kole lands. An additional crop during the usual mundakan season (September-December) is suggested for the entire area. For this the bunds should be formed. Some areas have already been enclosed with permanent bunds with the assistance of the Minor Irrigation Department. The bunds have not been properly formed and the repairs of such bunds are costly. Unless the bunds are formed at proper height the mundakan crop would not be successful. Therefore this crop is not favoured by the farmers.

Puncha is the main crop which is raised during January-April. Towards the close of the North East monsoon, the bunds separating the deep kole from the rice fields are repaired, water from the fields are pumped out into the deep kole and sowing or transplanting done by January.

3.6 Characteristics of existing bund

The objective of laying permanent bunds is to keep out the flood waters of the river channel from entering the kole fields thereby preventing submergence and causing less damage to the cultivated crop. The fill material is lateritic in nature and the foundation composed of clay which is plastic in nature. The top of the bunds are kept at the lowest of 1.8 m. to get a free board of 60 cm. when water is retained at 1.2 m. The bunds have 2 m. top width and side slope of 1 1/2:1 (Refer Fig.5).

3.7 Soil analysis

In order to study the feasibility of the permanent bund it is necessary that the soil conditions of the area as well as the fill mateial is studied. Two undisturbed soil samples and a disturbed sample of the foundation material (soil of the kole land) were collected from the site. A disturbed sample of the fill or borrow material were also collected. The samples were then taken to KERI, Trichur for soil analysis.

Specific gravity, Natural moisture content, bulk density, voids ratio, porosity, liquid limit, plastic limit, plasticity index, sieve analysis and angle of internal friction in degrees and cohesion (by direct shear test) were the various tests done on the undisturbed sample of the kole land. Optimum moisture content, maximum dry density, specific gravity, liquid limit, plastic limit, plasticity index, sieve analysis and angle of internal friction in degrees and cohesion (by direct shear test) and permeability were the various tests done on the disturbed sample of the fill material.

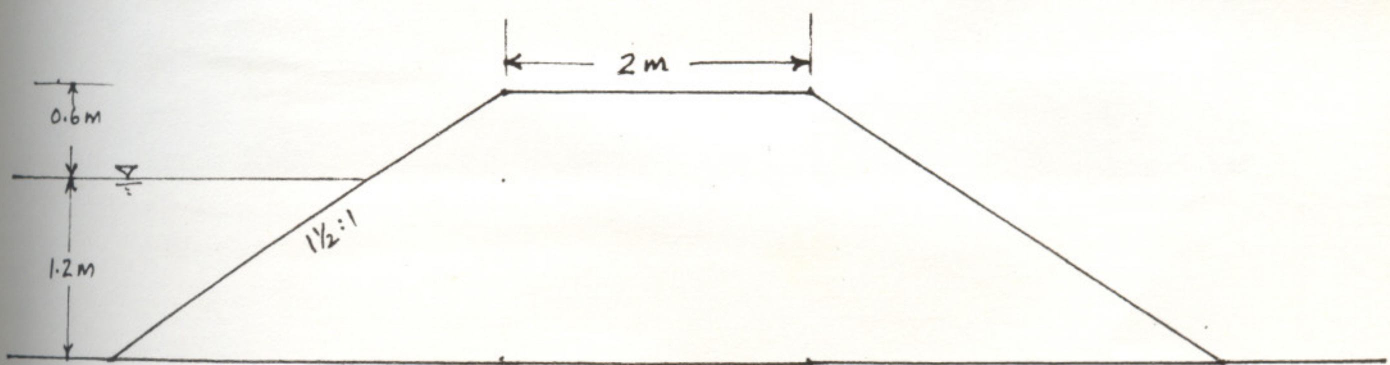


FIG. 5 CHARACTERISTICS OF EXISTING BUND

These tests are briefly described as follows:

3.7.1 Moisture content

The moisture content of soil samples were determined by gravimetric method. The soil samples were taken in air tight aluminium containers. The samples were weighed and were dried in an oven at 105°C for about 24 hours. After removing from the oven they were cooled slowly to room temperature and then weighed. The difference in weight is the amount of moisture in the soil.

Moisture content (dry basis)

$$= \frac{\text{(weight of wet soil - weight of dry soil)}}{\text{Weight of dry soil}} \times 100\%$$

3.7.2 Specific gravity

The specific gravity of the soil solids was determined using the 50 ml density bottle. The mass M_1 of the empty, dry bottle was first taken. A sample of oven dried soil which was cooled in a dessicator was taken in the bottle and its mass M_2 found out. The bottle was then filled with distilled water gradually letting off the entrapped air by shaking the bottle. Then the mass M_3 of the bottle, soil and water (full up to the top) was taken. Finally the bottle was emptied completely and thoroughly washed, and clean water was filled to the top and the mass M_4 was taken. Based on these four observations, the specific gravity was computed as follows:

$$\text{Specific gravity, } G = \frac{\text{Dry mass of soil}}{\text{Mass of water of equal volume}}$$

$$= \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

3.7.3 Bulk density, voids ratio and porosity

In order to determine the bulk density, void ratio and porosity of foundation soil, it is required to obtain an uncompacted soil sample of known volume. An undisturbed soil sample was collected with a mould of weight 'W_1'. The weight 'W_2' of moist soil including mould was noted. The volume of soil will be the same as the volume of the core sampler 'V'.

Then,

i. $$\text{Bulk density} = \frac{W_2 - W_1}{V} \text{ g/cc}$$

$$\text{Dry weight of soil, } W_3 = \frac{W_2 - W_1}{1+m}$$

where, m is the normal moisture content of soil

Absolute volume of soil solids, $V_s = \dfrac{V_3}{G}$

where, G is the specific gravity of soil

Volume of voids $= V - V_s$

ii. Therefore, void ratio, $e = \dfrac{V - V_s}{V_s}$

iii. Porosity, $n = \dfrac{V - V_s}{V}$

3.7.4 Atterberg limits

Atterberg limits which are most useful for engineering purposes are liquid limit and plastic limit. These limits are expressed on a water content index.

3.7.4.1 Liquid limit

The liquid limit was determined using the standard liquid limit apparatus shown in Fig.6. The apparatus consists of a hard rubber base over which a brass cup drops through a desired height. The brass cup can be raised and lowered to fall on the rubber base with the help of a handle. The height of fall of the cup can be adjusted with the help of adjustable screws. Before starting the test, the height of fall of the cup was adjusted to 1 cm. The

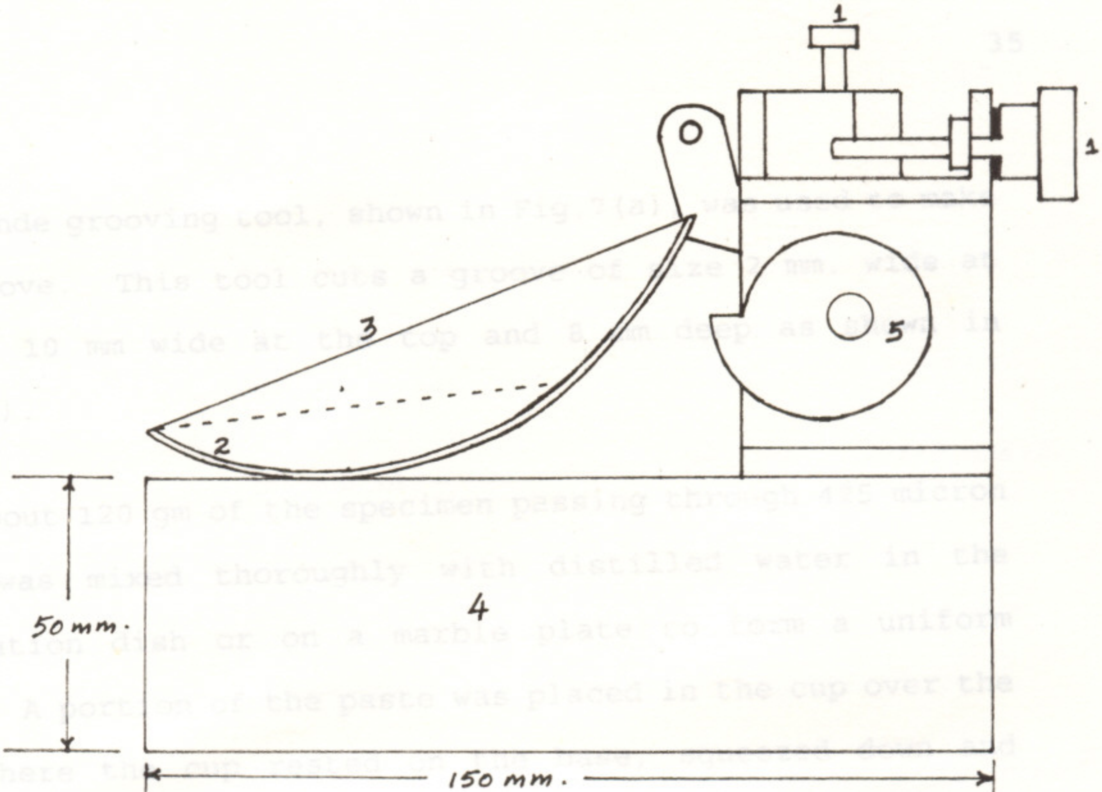


FIG. 6 (a) SIDE VIEW

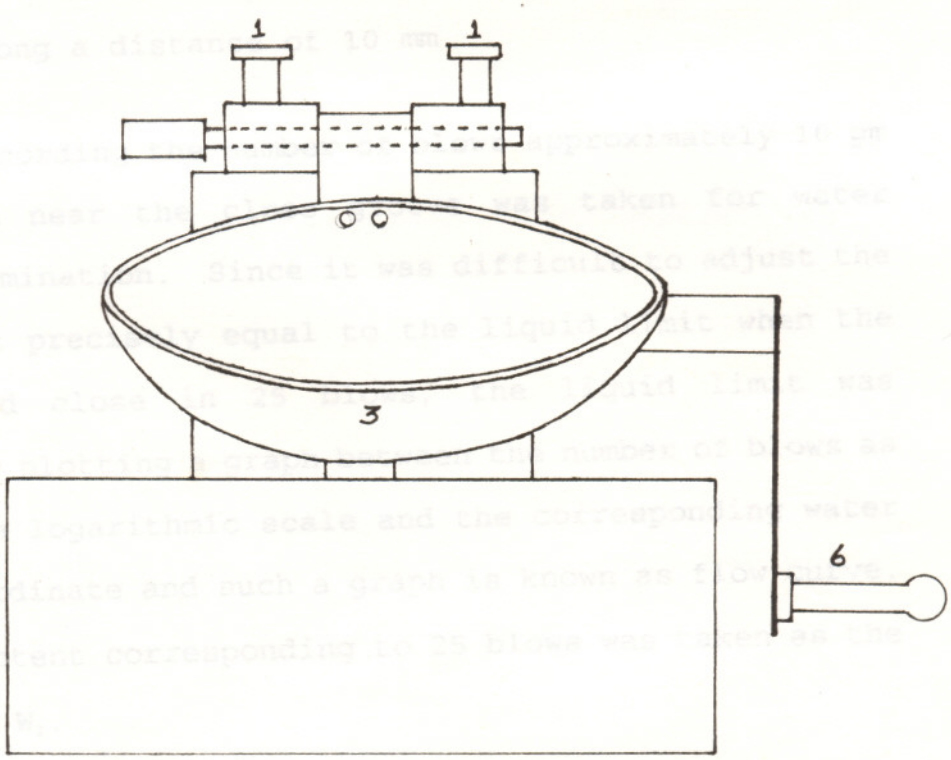


FIG. 6 (b) FRONT VIEW

1- ADJUSTING SCREWS, 2- SOIL, 3- BRASS CUP, 4- HARD RUBBER BASE
5- CAM, 6- HANDLE

FIG 5. LIQUID LIMIT APPARATUS

Casagrande grooving tool, shown in Fig.7(a), was used to make the groove. This tool cuts a groove of size 2 mm. wide at bottom, 10 mm wide at the top and 8 mm deep as shown in Fig.7(c).

About 120 gm of the specimen passing through 425 micron sieve was mixed thoroughly with distilled water in the evaporation dish or on a marble plate to form a uniform paste. A portion of the paste was placed in the cup over the spot where the cup rested on the base, squeezed down and spread into position and the groove is cut in the soil pat. The handle was rotated at a rate about 2 revolutions per second and the number of blows were counted until the two parts of the soil sample came into contact at the bottom of the groove along a distance of 10 mm.

After recording the number of blows approximately 10 gm of soil from near the close groove was taken for water content determination. Since it was difficult to adjust the water content precisely equal to the liquid limit when the groove should close in 25 blows, the liquid limit was determined by plotting a graph between the number of blows as absassae on a logarithmic scale and the corresponding water content as ordinate and such a graph is known as flow curve. The water content corresponding to 25 blows was taken as the liquid limit W_2.

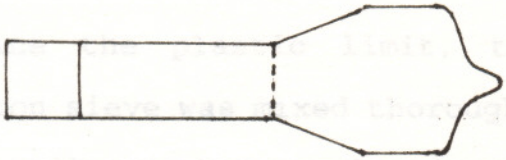


FIG 7.(a) CASAGRANDE GROOVING TOOL - TOP VIEW

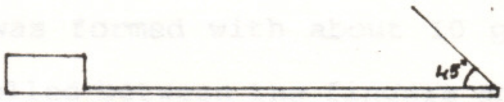


FIG 7 (b) CASAGRANDE GROOVING TOOL - SIDE VIEW

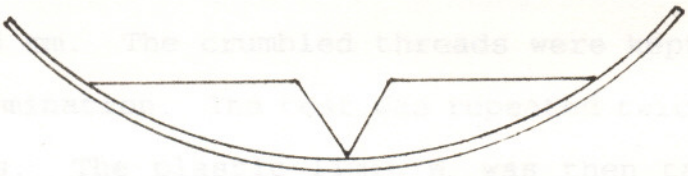


FIG 7 (c) DIVIDED SOIL CAKE BEFORE TEST

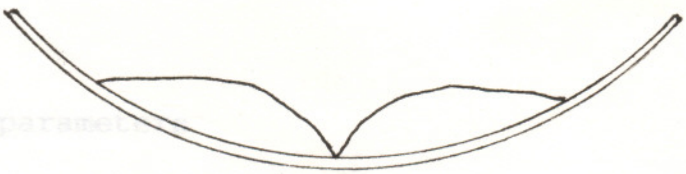


FIG 7 (d) SOIL CAKE AFTER TEST

FIG 7 CASAGRANDE GROOVING TOOL WITH SOIL CAKE BEFORE AND AFTER TEST

3.7.4.2 Plastic limit

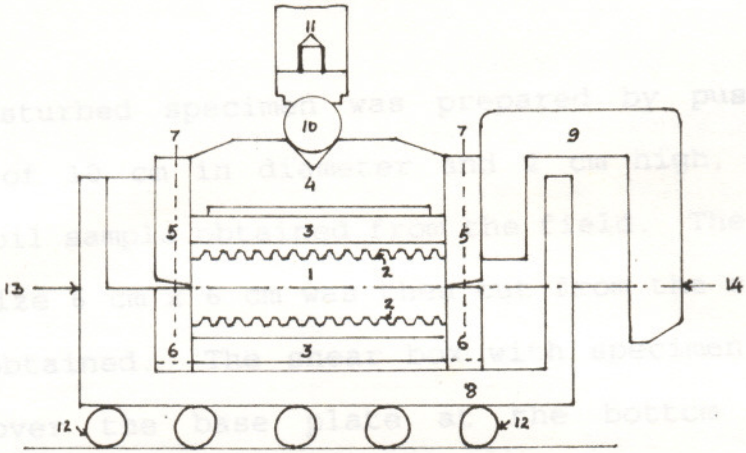
To determine the plastic limit, the soil specimen passing 425 micron sieve was mixed thoroughly with distilled water until the soil mass became plastic enough to be easily moulded with fingers. The plastic soil mass is left for enough time to allow water to permeate through the soil mass. A ball was formed with about 10 gm of this plastic soil mass and rolled between the fingers and a glass plate or marble plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. When a diameter of 3 mm was reached, the soil was remoulded again into a ball. This process of rolling and remoulding was repeated until the thread starts just crumbling at a diameter of 3 mm. The crumbled threads were kept for water content determination. The test was repeated twice with more fresh samples. The plastic limit W_p was then taken as the average of three water contents.

The plasticity index was calculated from the relation:

$Ip = W_L - W_P$

3.7.5 Shear parameters

Shear parameters were determined by direct shear test. The materials and equipments used for this test were shear box apparatus as shown in the Fig.8.



1 - SOIL SPECIMEN, 2 - METAL GRIDS, 3 - POROUS STONES, 4 - LOADING PAD, 5 - UPPER PART, 6 - LOWER PART, 7 - SCREW TO FIX TWO HALVES OF SHEAR BOX, 8 - CONTAINER FOR SHEAR BOX, 9 - U-ARM, 10 - STEEL BALL, 11 - LOADING YOKE, 12 - ROLLERS, 13 - SHEAR FORCE APPLIED BY JACK. 14 - SHEAR RESISTANCE MEASURED BY PROVING RING

FIG. 8 PARTS OF A SHEAR BOX

The apparatus consisted of a two piece shear box of square or circular cross section, a set of weights for normal load, loading frame, proving ring with dial gauge, micrometer dial guage to measure horizontal and vertical displacements during shear, spatula, straight edge, sample trimmer and a stop watch.

The undisturbed specimen was prepared by pushing a cutting ring of 10 cm in diameter and 2 cm high, in the undisturbed soil sample obtained from the field. The square specimen of size 6 cm x 6 cm was then cut from the circular specimen so obtained. The shear box with specimen, plain grid plate over the base plate at the bottom of the specimen, and plain grid plate over the top of the specimen, was fitted into position. The serrations of the grid plates were placed at right angles to the direction of shear. As the porous stones were not used in the undrained tests, plain plates of equal thickness were placed one at the bottom and the other at the top of the two grids so as to maintain the shear plane in the sample in the middle of its thickness. The loading pad was placed on the top of the plain grid plate. Both the parts of the box were tightened together by the fixing screws and water was poured inside the water jacket so that the sample does not get dry during the test.

The shear box assembly was mounted on the load frame (or shearing machine). The lower part of the shear box was set to bear against the load jack and the upper part of the box to bear against the proving ring. The dial of the proving ring was set to zero and the loading yoke was placed on top of the loading pad and the dial gauge was adjusted to zero to measure the vertical displacement in the soil sample. Proper normal weight was placed on the hanger of the loading yoke, so that this weight plus the weight of the hanger equals the required normal load. the reading of the vertical displacement dial gauge was noted. The locking screw was then removed so that both the parts are free to move against each other. Then the upper part was raised slightly above the lower parts by about 1 mm by turning the spacing screws.

The test was conducted by applying horizontal shear load to failure or to 20 per cent longitudinal displacement whichever occurred first. The rate of strain may vary from 1 to 2.5 mm per minute. The stop watch was started immediately at the start of the application of the shear load. The readings of the proving ring dial gauge, longitudinal displacement gauge and vertical displacement gauge were taken at regular time intervals. At the end of the test, the specimen is removed from the box and its final water content is determined. The above steps were repeated on three or four identical specimens, under varying normal loads.

3.7.6 Permeability

The permeability of the fill material was determined by the falling head test. A stand pipe of known cross sectional area was fitted over the permeameter, and water was allowed to run down. The water level in the stand pipe constantly fell as water flowed down. Observations were taken after steady state of flow was reached. The head at any time 't' will be equal to the difference in the water level in the stand pipe and bottom tank as shown in the Fig.9.

Let h_1 and h_2 be heads at time intervals t_1 and t_2 $(t_2>t_1)$ respectively. Hence from Darcy's law, Permeability coefficient,

$$K = \frac{aL}{At} \log_e h_1/h_2$$

$$= 2.3 \frac{aL}{At} \log_{10} h_1/h_2$$

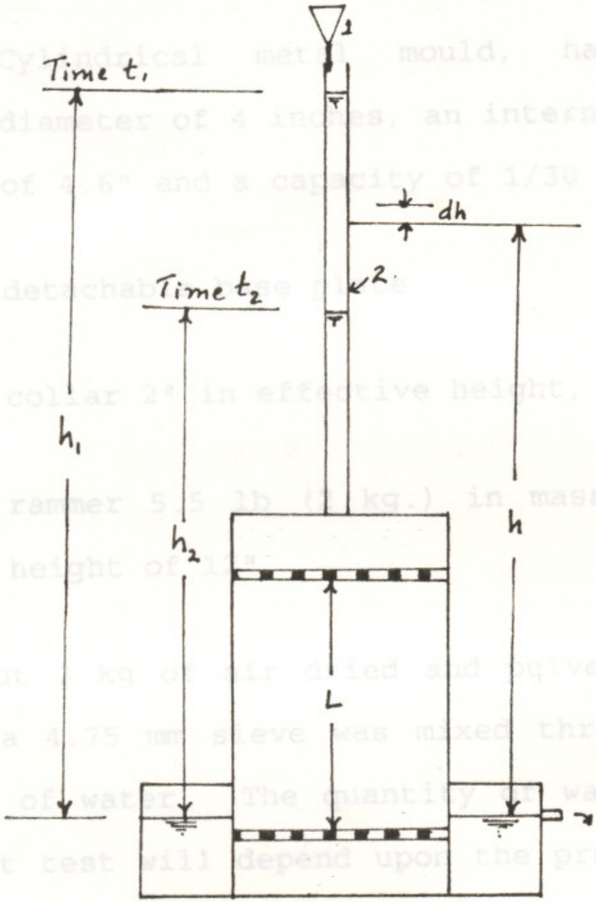
where,

$t = t_2 - t_1$

a = cross sectional area of stand pipe

A = cross sectional area of soil sample

L = length of soil sample



1- FUNNEL, 2- STAND PIPE

FIG 9. DIAGRAMMATICAL REPRESENTATION OF A FALLING HEAD TEST ARRANGEMENT

3.7.7 Optimum moisture content and dry bulk density

Optimum moisture content and dry bulk density of fill material was determined by Standard Proctor test. The test equipment consists of

(i) Cylindrical metal mould, having an internal diameter of 4 inches, an internal effective height of 4.6" and a capacity of 1/30 cu.ft.

(ii) detachable base plate

(iii) collar 2" in effective height, and

(iv) rammer 5.5 lb (2 kg.) in mass falling through a height of 12"

About 3 kg of air dried and pulverised soil, passing through a 4.75 mm sieve was mixed throughly with a small quantity of water. The quantity of water to be added for the first test will depend upon the probable optimum water content for the soil. The initial water content may be taken as 4 per cent for coarse grained soil and 10 per cent for fine grained soils. The empty mould attached to the base plate was weighed without collar. The collar was then attached to the mould. The mixed and mature soil was placed in the mould and compacted by giving 25 blows of the rammer uniformly distributed over the surface, such that the compacted height of soil was about 1/3rd the height of the mould.

Before putting the second instalment of soil, the top of the first compacted layer was scratched with the help of any sharp edge. The second and third layers were similarly compacted, each layer being given 25 blows. The last compacted layer should project not more than 6 mm into the collar. The collar was removed and the excess soil was trimmed off to make it level with the top of mould. The weight of the mould, base plate and the compacted soil was then taken. A representative sample was then taken from the centre of the compacted specimen and was kept for water content determination. Bulk density 'γ' and the corresponding dry density 'ρd' for the compacted soil were calculated from the following relation.

$$\gamma = \frac{M}{V} \ (g/cm^3) \text{ and}$$

$$\rho_d = \frac{\gamma}{1+w} \ (g/cm^3)$$

where,

M = mass of wet compacted specimen

w = water content (ratio)

V = volume of the mould, 1/3 cu.ft.

The compacted soil was taken out of the mould, broken with hand and remixed with raised water content (by 2 or 4 per cent). After allowing time for maturing, the soil was compacted in the mould in three equal layers, as described above, and the corresponding dry density 'ρ_d' and water content 'w' were thus determined. The test was repeated on soil samples with increasing water contents and the corresponding dry density 'ρ_d' obtained was thus determined. A compaction curve was thus plotted between the water contents as abscissae and the corresponding dry densities as ordinates. The dry density goes on increasing as the water content was increased, till maximum density was reached. The water content corresponding to the maximum density is called the optimum water content w_0.

3.7.8 Grain size distribution

The grain size distribution of the soils were determined by sieve analysis. The soil samples were hand crushed and kept in an oven at 105°C for 24 hours. An amount of oven dried samples were weighed out for sieve analysis. The sieves selected were of 10 mm, 9.53 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600 micron, 425 micron, 300 micron, 150 micron and 75 micron IS sieve size. The sieves were arranged in ascending order and kept in a sieve shaker. The sample is transferred to the top sieve and the sieve shaker is operated for 10 minutes. The soil particles retained in each sieve and in the bottom collector plate are weighed separately. The percentage of soil retained on each sieve is calculated on the basis of total mass of soil sample taken and from these data the per cent passing through each of the sieve is calculated.

3.8 Modifications to existing bund

3.8.1 Design procedure

3.8.1.1 Height of bund

The total height of bund was determined by adding to the depth of water a sufficient freeboard.

3.8.1.2 Freeboard

This is a margin between the water level and the top of embankment. The height of freeboard varies with the importance of the embankment and the provisions of safety essentials and upon the height of waves which depends upon the depth, length or fetch of the water and wind conditions.

∴ The height of bund = Depth of water + freeboard

The freeboard that corresponds to a particular depth of water is obtained from a table giving standard values (refer Appendix I).

3.8.1.3 Side slope

Knowing the height of bund including freeboard, the cohesion and density of the material of bund, the safety number value corresponding to the above characteristics can be found out by the following formula.

$$\text{Stability number, SN} = \frac{C}{\gamma x h x F}$$

where,

F = factor of safety assumed as

C = cohesion, kg/cm^2

γ = density, kg/cm^3

h = height of bund

Since stability number SN and angle of internal friction ϕ are known, from the Taylor's chart, (shown in Fig.10) the stability number, angle of slope 'i' can be found out. Then the side slope is calculated.

3.8.1.4 Top width

Top width of bunds vary with the height and purpose to which the bund is being put. The minimum top width for bunds upto 5 m in height should be 2.4 m. The top of the bund should be wide so as to allow transportation.

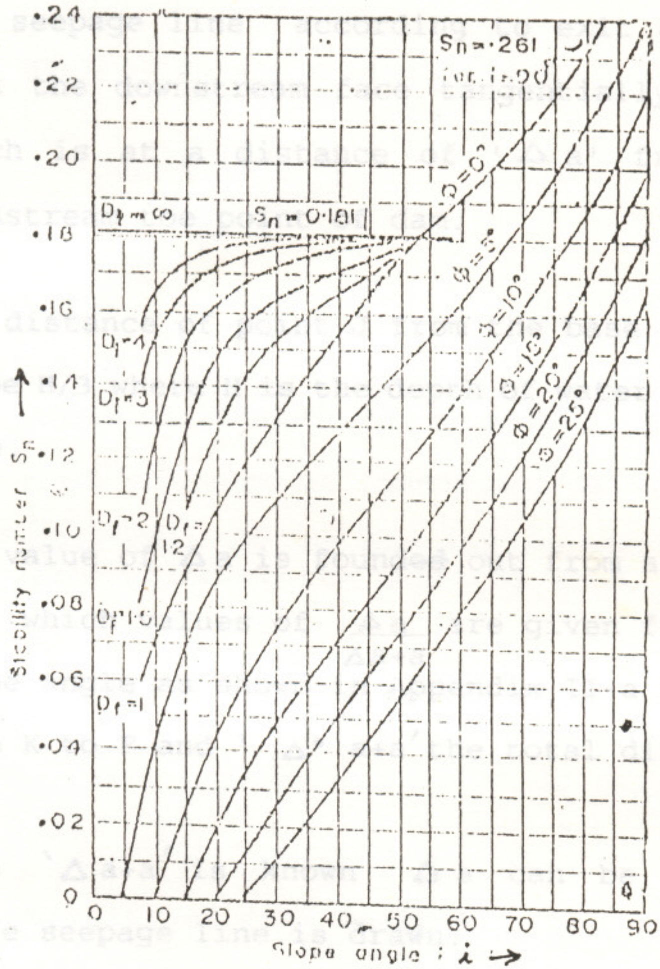


FIG. 10 CHART OF TAYLORS STABILITY NUMBER

3.8.2 Seepage through the embankment

The seepage line is drawn by the general solution by Casagrande based on the following assumptions.

(i) The seepage line according to exit conditions must meet the downstream face tangentially at a point K which is at a distance of 'Δ a' from J.F is the downstream toe point of dam.

(ii) The distance of point J from the base of dam is taken to be H/3 where H is the depth of water on the upstream side.

(iii) The value of Δa is founded out from a standard table for which values of $\frac{\Delta a}{\Delta a+a}$ are given for a particular slope angle as shown in Appendix II·a is the distance from K to F and 'Δ a+a' the total distance JF.

Since 'Δ a+a' is known Δ a can be found and the approximate seepage line is drawn.

3.8.4 Foundation design considerations

3.8.4.1 Design requirement for shear resistance

The foundation material being clayey in nature, stability analysis of foundation against shear is to be done by referring to Fig.11.

Maximum unit shear = $S_{max} = 1.4\ S_a$

This maximum shear occurs at 0.4 B from poiint J

The unit shear strength below toe K,

$$S_1 = C + \gamma_f\ h_2 \tan \phi$$

The unit shear strength at point J

$$S_2 = C + \gamma_m\ h_1 \tan \phi$$

Therefore the average shear strength,

$$S = \frac{S_1 + S_2}{2}$$

The facator of safety against shear,

$$F.S = \frac{S}{Sa}$$

The slope was selected so that the factor of safety is more than 1.5 for the stability of foundation against shear.

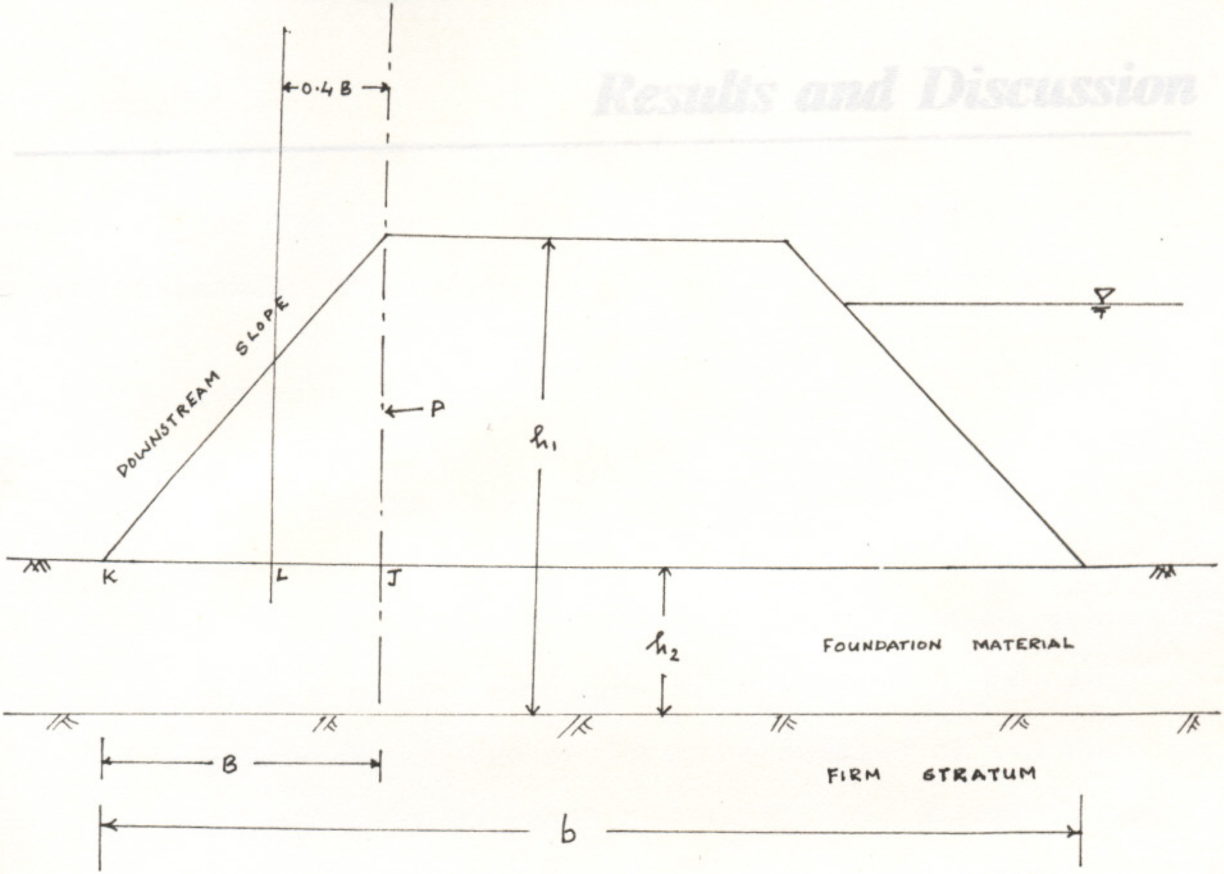


FIG 11. STABILITY ANALYSIS OF FOUNDATION AGAINST SHEAR

RESULTS AND DISCUSSION

The results of the analyses and investigations conducted on the soil and prevailing bund design with proposed design criteria are described in this chapter.

4.1 Soil analysis

Natural moisture content, specific gravity, bulk density, voids ratio, porosity, liquid limit, plastic limit, Angle of internal friction and cohesion (Direct shear tests were the various tests that were carried out in the Soil Mechanics Laboratory on two undisturbed samples of the soil of kole land, (Samples No.18592 and 18593) the observations being shown in Appendix III, IV, V, VI, VII and VIII.

Specific gravity, liquid limit, plastic limit, angle of internal friction and cohesion (Direct shear test), permeability, optimum moisture content and maximum dry density were the tests that were carried out on a disturbed sample of the soil of the fill material (Sample No.18594) the observations being shown in Appendix IV, VI, VII, VIII, IX and X.

The results of the various tests on the undisturbed sample of the kole land and disturbed sample of till material are shown in Table 1 and 2.

Table 1. Test results of soil of kole land

Sample No.	18592	18593
Nature of sample	Undisturbed	Undisturbed
Texture	Sandy clay	Sandy clay
Colour	French grey	French grey
Specific gravity	2.9	2.65
Natural moisture content	15	17
Bulk density	2.07	1.92
Void ratio	0.62	0.61
Porosity	38	38
Liquid limit	20	23
Plastic limit	-	18
Plasticity index	-	5
Class	SC	SC
Clay %	15	16
Silt %	10	22
Sand %	75	62
Gravel %	0	0
Angle of internal friction (Degrees)	30	23
Cohesion (kg/cm^2)	0.1008	0.1764

Table 2. Test results of fill material

Sample No.	18594
Nature of sample	Disturbed
Texture	Gravelly earth
Colour	Brick red
Optimum moisture content %	14
Maximum dry density	1.896
Specific gravity	3.01
Liquid limit	39
Plastic limit	26
Plasticity index	13
Class	GC
Clay %	14
Silt %	9
Sand %	37
Gravel %	40
Angle of internal friction (Degrees)	27
Cohesion in kg/sq.cm	0.0378
Coeff. of permeability cm/sec	3.572×10^{-5}

4.1.1 Suitability of the fill material

The fill material is found to have a platicity index of 13 and having a sand content not less than 35 per cent by weight. It is also found to be of low permeability of 3.572 x 10^{-5} cm/sec at a proctor density of 1.896 g/cc.

The fill material belongs to the class GC with fairly good compaction characteristics, the soil type gives stable embankments and requires limited seepage control.

Therefore, considering the above characteristics the soil is recommended for use as fill material.

4.1.2 Foundation characteristics

The foundation material (soil of the kole land) belongs to the class SC which has good to fairly good bearing value of 150 kN/m^2 and coefficient of permeability ranging from 10^{-6} to 10^{-3} cm/s.

4.2 Modifications to existing bund

4.2.1 Design procedure

4.2.1.1 Height of bund

As the depth of water rarely exceeds 2 m in the deep kole, the total height of bund was obtained by adding to the depth of water a freeboard of 0.91 m as obtained from the Appendix I.

$$\therefore \text{ The total height of bund} = 2 + 0.91 \text{ m}$$
$$= 2.91 \text{ m}$$
$$\simeq 3 \text{ m}$$

4.2.1.2 Side slope

Knowing the height of bund the stability number was found out from the following formula

$$\text{Stability number, SN} = \frac{C}{\gamma \times h \times F} \quad \text{(Take F=2)}$$

where,

F = factor at safety

C = cohesion of fill material in kg/sq.cm

γ = density of fill material in kg/cu.cm

h = height of bund in cm

$$\therefore \text{SN} = \frac{0.0378 \times 1000}{2 \times 1.896 \times 2.91 \times 100} = 0.034$$

knowing the stability number, SN, and the angle of internal friction ϕ, the angle of slope i was found from the Taylors stability chart as depicted in Fig.10.

Angle of internal friction, $\phi = 27°$

Stability no., SN = 0.034

From Fig.10 the angle of slope i corresponding to the above two values is selected as the angle of slope.

Therefore, i obtained from the chart is 45°.

4.2.1.3 Top width

Top width was selected as 2.4 m since the minimum top width for bunds upto 5 m height should be 2.4 m.

∴ The bund cross section with its complete dimensions is shown in Fig.12.

4.2.2 Seepage through the embankment

The appropriate seepage line is drawn as illustrated in Fig.13..

Since the dam is homogenous and is located on an impervious foundation, toe drains should be placed so as to divert the seepage line from the downstream face.

Placing of rip rap or store pitching on the side slopes will protect the side of the bund in case of wave action due to increased currents. Since the area is subjected to

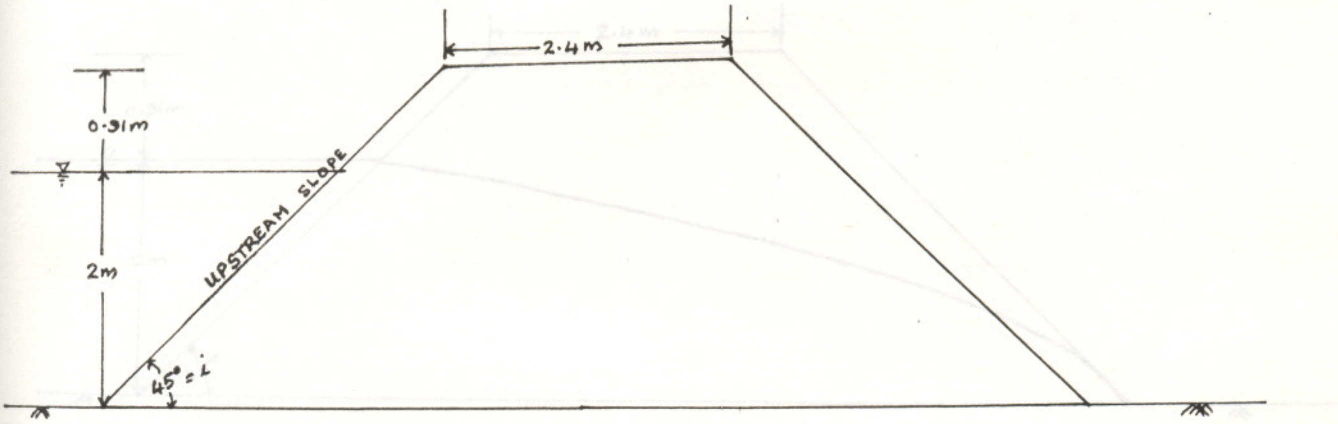


FIG 12 - MODIFIED CROSS SECTION OF BUND

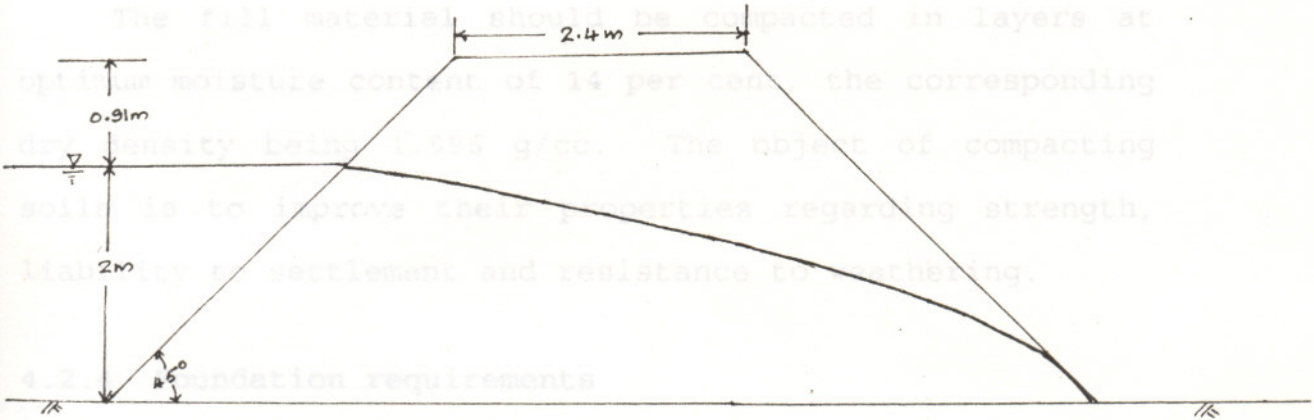


FIG. 13 - SEEPAGE LINE OF THE BUND

increase in flood currents during the monsoons this requirement is essential.

4.2.3 Compaction

The fill material should be compacted in layers at optimum moisture content of 14 per cent, the corresponding dry density being 1.896 g/cc. The object of compacting soils is to improve their properties regarding strength, liability to settlement and resistance to weathering.

4.2.4 Foundation requirements

Stability analysis of foundation against shear is done by referring Fig.14.

The total horizontal shear down to the boundary,

$$P = \frac{h_1^2 - h_1^2}{2} \cdot \gamma_m \cdot \tan^2\left(45° - \frac{\phi'}{2}\right)$$

where,

ϕ' = equivalent angle of friction

$$\tan \phi' = \frac{(\gamma_m \cdot h_1 \cdot \tan \phi + C)}{\gamma_m \cdot h_1}$$

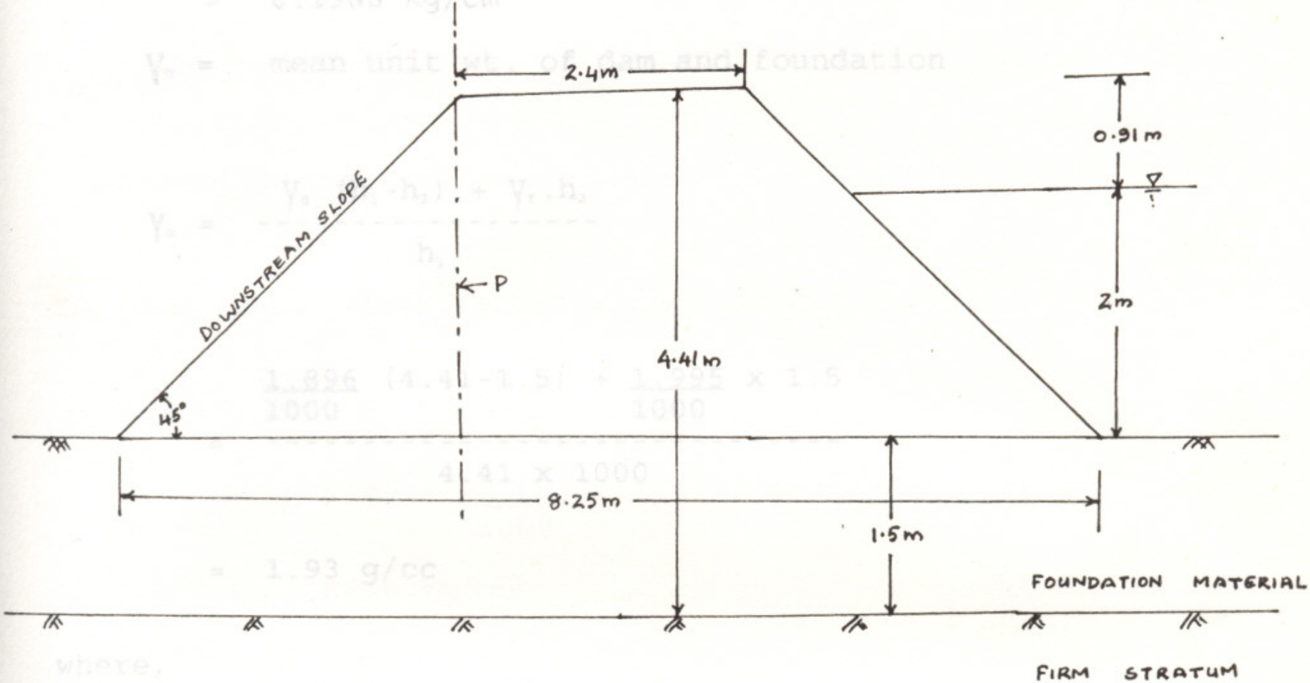


FIG. 14 - STABILITY ANALYSIS OF FOUNDATION AGAINST SHEAR FOR MODIFIED BUND

where,

ϕ = angle of internal friction of foundation material = 27°

C = unit cohesion of foundation material

= 0.1386 kg/cm^2

γ_m = mean unit wt. of dam and foundation

$$\gamma_m = \frac{\gamma_d\ (h_1 - h_2) + \gamma_f . h_2}{h_1}$$

$$= \frac{\frac{1.896}{1000}(4.41-1.5) + \frac{1.995}{1000} \times 1.5}{4.41 \times 1000}$$

= 1.93 g/cc

where,

γ_d = density of dam material = 1.896 g/cc

γ_f = density of foundation material = 1.995 g/cc

$$\therefore \tan \phi' = \frac{\frac{1.93}{1000} \times 4.41 \times 1000 \times \tan 27° + 0.1386}{\left(\frac{1.93}{1000} \times 4.41 \times 1000\right)}$$

= 0.525

ϕ' = 27°

$\therefore$ The total horizontal shear down to the right boundary,

$$P = \frac{(4.41)^2 - (1.5)^2}{2} \times 1.93 \times \tan^2 (45° - \frac{27°}{2})$$

$$P = 6.23$$

The average unit shear, $S_a = \frac{P}{b} = \frac{6.23}{8.25} = 0.755$

where b = base width of bund

Maximum unit shear, $S_{max} = 1.4\ S_a = 1.4 \times 0.755$

$= 1.057$

The unit shear strength below toe, K,

$$S_1 = C + \gamma_f . h_2 \tan \phi$$

$$= 0.1386 + (\frac{1.995}{1000} \times 1.5 \times 1000 \times \tan 27°)$$

$$= 1.6633\ kg/cm^2$$

The unit shear strength at point J

$$S_2 = C + \gamma_m . h_1 \tan \phi$$

$$= 0.1386 + (\frac{1.93}{1000} \times 4.41 \times 1000 \times \tan 27°)$$

$$= 4.475\ kg/cm^2$$

Therefore the average shear strength,

$$S = \frac{S_1 + S_2}{2} = \frac{1.6633 + 4.47}{2} = 3.0691\ kg/cm^2$$

The factor of safety against shear,

$$F.S. = \frac{S}{S_{max}} = \frac{3.0691}{1.057} = 2.89$$

Since the factor of safety obtained is more than 1.5 the foundation is relatively stable against shear.

The underlying strata has a permeability ranging around 10^{-3}cm/s, so vertical drainage wells about 1.5 times the height of bund are to be placed below the bund. Loose gravel should be placed in the drainage wells (Refer Fig.15).

4.3 Possible reasons for the breaching of bunds in the Ponnani koles with further suggestions

1. Erosion due to velocity of water, action of waves, rain and wind. Erosion causes slipping. Stone rivetment or pitching should be done.

2. Overtopping due to insufficient height of freeboard. Sufficient treeboard should be provided as the area is subjected to increased flow during the monsoons.

3. Percolation and leakage due to insufficient ramming of the embankment. The leakage water washes away the soil and caves are formed in the bund. The fill material

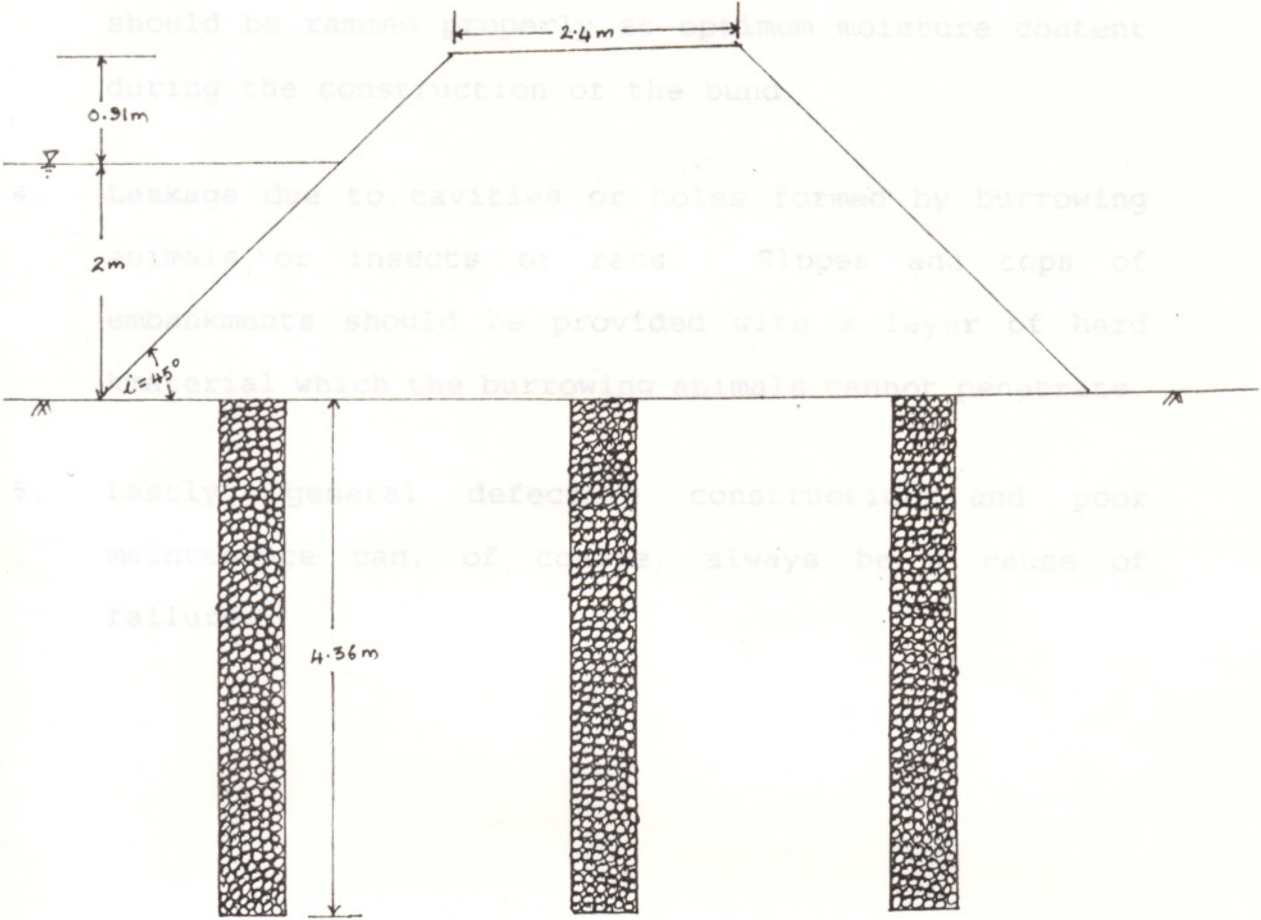


FIG.15 PLACEMENT OF DRAINAGE WELLS BELOW THE BUND

should be rammed properly at optimum moisture content during the construction of the bund.

4. Leakage due to cavities or holes formed by burrowing animals or insects or rats. Slopes and tops of embankments should be provided with a layer of hard kmaterial which the burrowing animals cannot penetrate.

5. Lastly, general defective construction and poor maintenance can, of course, always be a cause of failure.

SUMMARY AND CONCLCUSION

The 'Kole lands' are a major rice belt in Kerala and comprise of a unique agroecologic zone the productivity ranging from 5-8 tonnes per ha. But this area has no natural provision for drainage and lie submerged for most part of the year. This leads to the cultivation of only one crop from January to April during the absence of floods i.e. before the onset of the South West Monsoons.

This condition can be improved if permanent bunds are built to separate the rice fields from the deep kole and can facilitate the cultivation of a second crp (Mundakan) from September to December. But it was found that the existing temporary bunds breached every year when floods reached its maximum level and constant repairs of these bunds were found to be a financial strain. It was with this view in mind that a case study was conducted on soil properties of the area and possible reasons for frequent breaching of bunds. Further suggestions and a modified design to that of the existing bund is made.

Soil analysis was done on undisturbed samples of the kole land (foundation material) and disturbed samples of fill material in the soil mechanics laboratory. The results of the soil analysis showed that the foundation material belonged to the soil class SC which has good to fairly good bearing value.

The fill material is found to have a plasticity index of 13 and having a sand content not less than 35 per cent by weight. It was also found to have a low permeability of 3.572×10^{-5} cm/sec at a proctor density of 1.896 g/cc. The fill material belongs to the class GC with fairly good compaction characteristics which gives stable embankments and requires limited seepage control. The fill material was hence recommended for construction of the bund.

Modifications to the existing bund was followed by using the Taylor's stability analysis. The total height of the bund was worked out to be 2.91 m with a slope angle of 45° and side slope of 1:1. A minimum top width of 2.4 m was suggested. The foundation was found to be safe against shear. Vertical drainage wells filled with coarse gravel with depth about 1 1/2 times the height of bund to be placed below the bund are suggested.

Possible reasons for the breaching of bunds and further suggestions were also put forward.

1. Erosion due to velocity of water, action of waves, rain and wind causes slipping for which stone rivetment or pitching should be done.

2. Overtopping due to insufficient freeboard for which sufficient freeboard should be provided as the area is subjected to increased flow during monsoons.

3. Percolation and leakage due to insufficient ramming of the embankment for which the fill material should be rammed properly at optimum moisture content during the construction of the bund.

4. Leakage due to cavities or holes formed by burrowing animals. The slopes and tops of bunds should be provided with a layer of hard material which the burrowing animals cannot penetrate. Consequently leakage due to cavities formed by burrowing animals can be avoided.

5. General defective construction which can be eliminated by proper care, maintenance and inspection during the construction process.

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Appendix-I

Relation between depth of water on upstream side and freeboard

Depth of water (m)	Free board (m)
1.5 - 3.0	0.91
3.0 - 4.6	1.22
4.6 - 6.0	1.52
>6.0	1.83

Appendix-II

Relation between slope angle i and $\frac{\Delta a}{a+\Delta a}$

Slope angle (i)	$\frac{\Delta a}{a+\Delta a}$
30°	0.36
60°	0.32
90°	0.26
120°	0.18
135°	0.14
150°	0.10
180°	0.00

Appendix-III

Observations of the test for natural moisture content for sample No. 18592

Dish number	151.00	30.00
Weight of dish (W_1), gm	37.36	36.31
Weight of dish + wet soil (W_2), gm	119.30	112.85
Weight of dish + dry soil (W_3), gm	108.50	103.30
Weight of moisture (W_2-W_3), gm	10.80	9.55
Weight of dry soil (W_3-W_1), gm	71.14	66.99

$$\text{Percentage of moisture} = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

	15.18	14.26

Observations of the test for natural moisture content for sample No. 18593

Dish number	176.00	103.00
Weight of dish (W_1), gm	39.60	37.95
Weight of dish + wet soil (W_2), gm	117.20	109.55
Weight of dish + dry soil (W_3), gm	104.80	100.10
Weight of moisture (W_2-W_3), gm	12.40	9.45
Weight of dry soil (W_3-W_1), gm	65.20	52.15

$$\text{Percentage of moisture} = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

	19.02	15.21

Appendix-IV

Observations of specific gravity test for sample No.18592

Sp. gravity bottle No.	:	20
Weight of Sp. gravity bottle, W_1, gm	:	861
Weight of bottle + dry soil, W_2, gm	:	1261
Weight of bottle + soil + water to fill the bottle, W_3, gm	:	2098
Weight of dry soil, $W_2 - W_1 = W_s$, gm	:	400
Weight of bottle + water only to fill, W_4, gm	:	1835.8
Weight of an equal volume of water = $(W_4 + W_s) - W_3$, gm	:	137.8
Sp. gravity of the soil $= \dfrac{W_s}{(W_4+W_s)-W_3}$	:	2.9

Observations of specific gravity test for sample No.18593

Sp. gravity bottle No.	:	26
Weight of Sp. gravity bottle, W_1, gm	:	736
Weight of bottle + dry soil, W_2, gm	:	1136
Weight of bottle + soil + water to fill the bottle, W_3, gm	:	1985
Weight of dry soil, $W_2 - W_1 = W_s$, gm	:	400
Weight of bottle + water only to fill, W_4, gm	:	1736
Weight of an equal volume of water = $(W_4 + W_s) - W_3$, gm	:	151
Sp. gravity of the soil $= \dfrac{W_s}{(W_4+W_s)-W_3}$	:	2.65

Observations of specific gravity test for sample No.18594

Sp. gravity bottle No.	:	20
Weight of Sp. gravity bottle, W_1, gm	:	861
Weight of bottle + dry soil, W_2, gm	:	1261
Weight of bottle + soil + water to fill the bottle, W_3, gm	:	2098
Weight of dry soil, $W_2 - W_1 = W_s$, gm	:	400
Weight of bottle + water only to fill, W_4, gm	:	1835.8
Weight of an equal volume of water = $(W_4 + W_s) - W_3$, gm	:	137.8
Sp. gravity of the soil $= \dfrac{W_s}{(W_4+W_s)-W_3}$	:	2.9

Appendix V

Observations of tests for bulk density, void ratio and porosity for sample No.18592

Sp. Gr. - 2.9; NMC (m) - 15%

		Trial I	Trial II
Weight of mould alone, gm	W_1	37.09	36.75
Weight of mould + moist soil, gm	W_2	83.35	84.25
Weight of moist soil, gm	W_2-W_1	46.26	47.50
Volume of moist soil, gm	V	22.67	22.67
Bulk density, gm/cc	$\frac{W_2-W_1}{V}$	2.04	2.10
Dry weight of soil, gm	$\frac{(W_2-W_1)}{1+m} = W_3$	0.23	41.30
Absolute volume of soil, in cc	$\frac{W_3}{G} = V_s$	13.87	14.24
Volume of voids	$V-V_s$	8.80	8.43
Void ratio (e)	$\frac{V-V_s}{V_s}$	0.64	0.59
Porosity (n)	$\frac{V-V_s}{V}$	38.82	37.00

Average bulk density : 2.07

Average voids ratio : 0.62

Average porosity : 38

Observations of tests for bulk density, void ratio and porosity for sample No.18593

Sp. Gr - 2.65;NMC (m) - 17%

		Trial I	Trial II
Weight of mould alone, gm	W_1	37.09	36.75
Weight of mould + moist soil, gm	W_2	80.70	80.30
Weight of moist soil, gm	W_2-W_1	43.61	43.55
Volume of moist soil, gm	V	22.67	22.67
Bulk density, gm/cc	$\frac{W_2-W_1}{V}$	1.92	1.92
Dry weight of soil, gm	$\frac{(W_2-W_1)}{1+m}$	37.27	37.22
Absolute volume of soil, in cc	$\frac{W_3}{G} = V_s$	14.06	14.05
Volume of voids, in cc	$V-V_s$	8.61	8.62
Void ratio (e), in cc	$\frac{V-V_s}{V_s}$	0.61	0.61
Porosity (n)	$\frac{V-V_s}{V}$	37.98	38.02

Average bulk density : 1.92

Average voids ratio : 0.61

Average porosity : 38

Appendix-VI

Observations of test for liquid limit for sample No.18592

Sl. No.	No. of blow	No. of dish	Wt. with wet soil (gm)	Wt. with dry soil (gm)	Wt. of dish (gm)	m.c. (%)
1	18	155	63.70	59.30	37.25	19.98
2	24	149	58.15	54.20	34.50	20.15
3	32	28	58.20	54.95	38.31	19.53
4	40	104	57.4	54.05	36.37	18.95

Observations of test for liquid limit for sample No.18593

Sl. No.	No. of blow	No. of dish	Wt. with wet soil (gm)	Wt. with dry soil (gm)	Wt. of dish (gm)	m.c. (%)
1	14	172	58.25	53.50	34.12	24.51
2	22	92	58.50	54.25	36.07	23.38
3	27	184	58.15	54.20	36.94	22.84

Observations of test for liquid limit for sample No.18594

Sl. No.	No. of blow	No. of dish	Wt. with wet soil (gm)	Wt. with dry soil (gm)	Wt. of dish (gm)	m.c. (%)
1	14	148	61.40	54.40	36.68	39.50
2	21	188	57.10	51.55	37.55	39.64
3	27	136	56.5	50.80	36.08	38.72
4	55	30	58.95	52.80	36.31	37.30

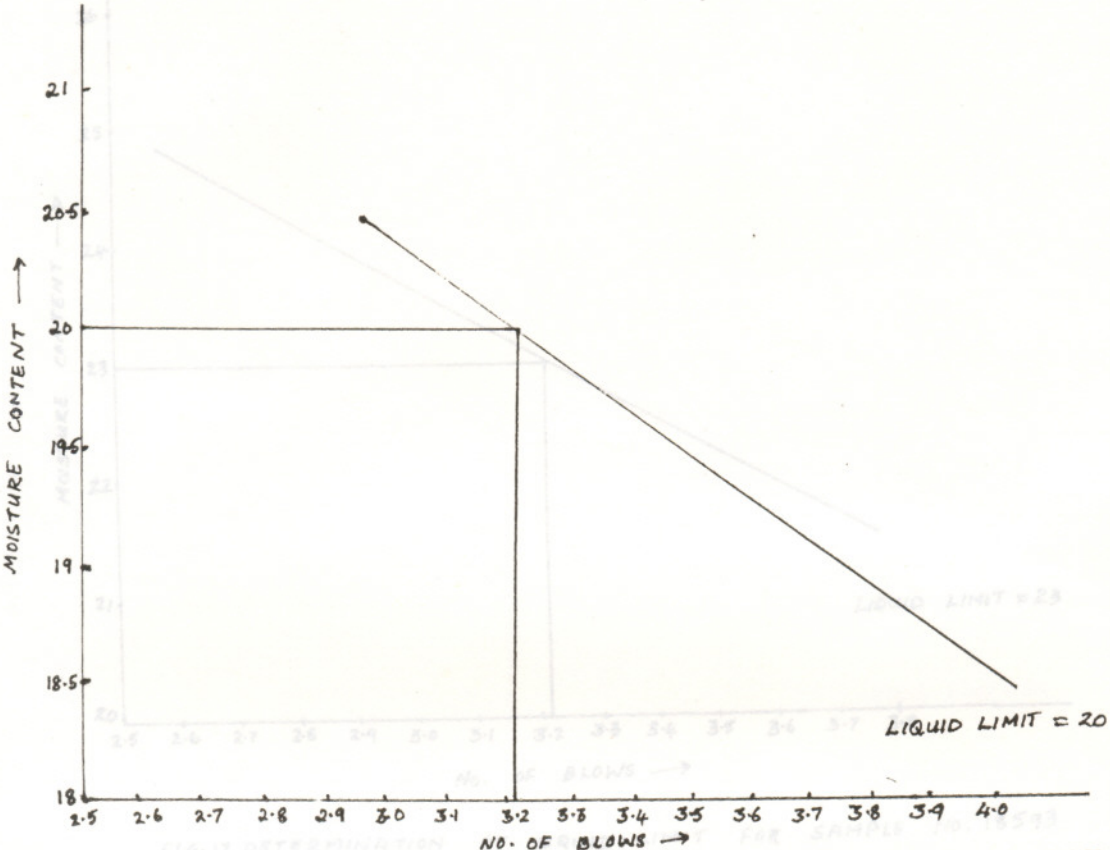

FIG. 16 - DETERMINATION OF LIQUID LIMIT FOR SAMPLE NO. 18592

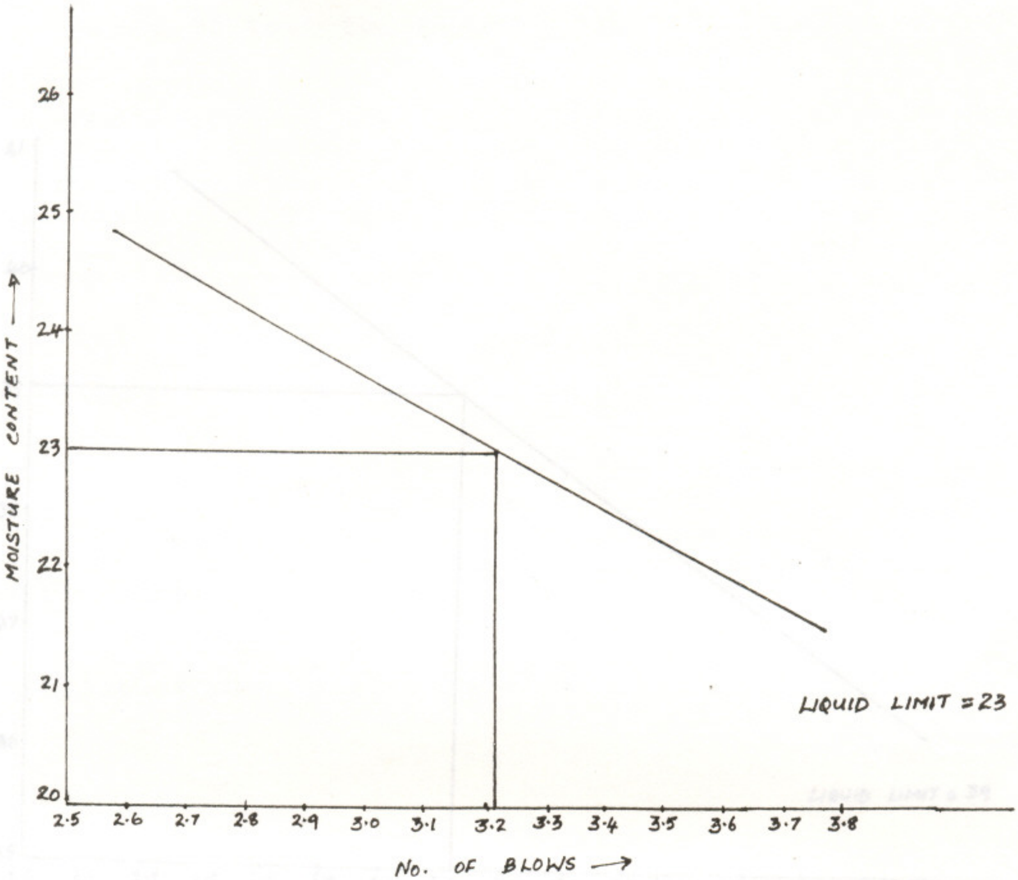

FIG. 17 DETERMINATION OF LIQUID LIMIT FOR SAMPLE NO. 18593

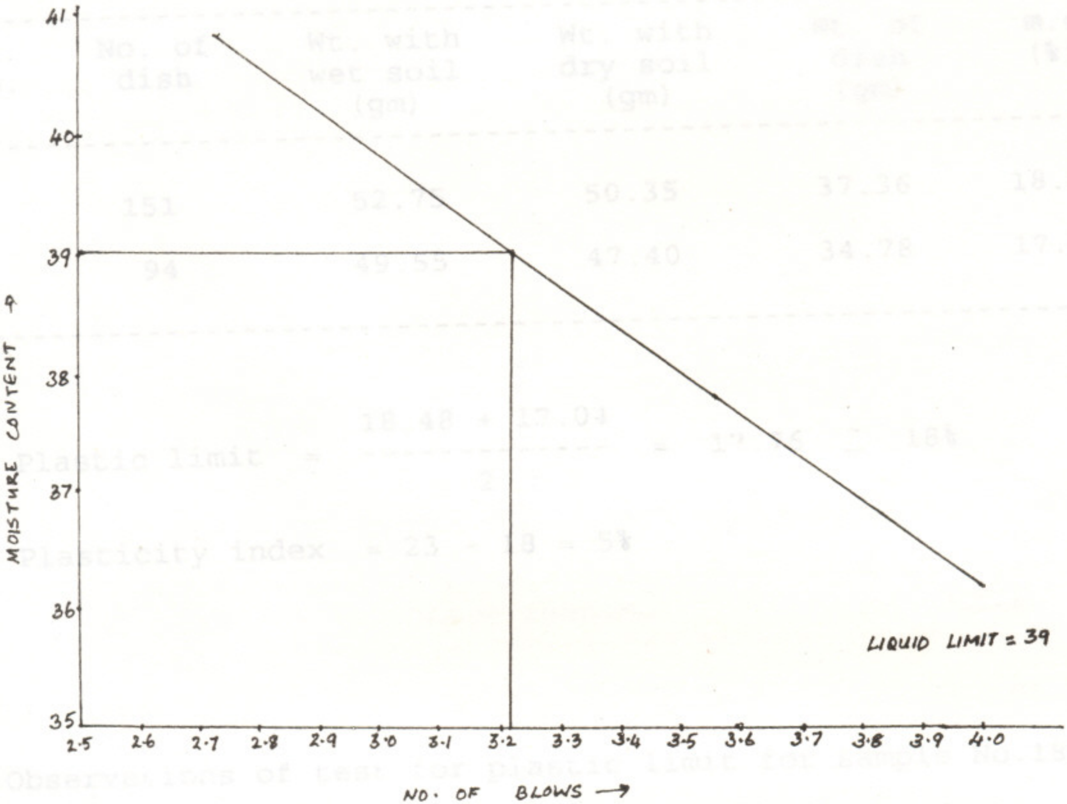

FIG 18 DETERMINATION OF LIQUID LIMIT FOR SAMPLE NO 18594

Appendix-VII

Observations of test for plastic limit for sample No.18593

Sl. No.	No. of dish	Wt. with wet soil (gm)	Wt. with dry soil (gm)	Wt. of dish (gm)	m.c. (%)
1	151	52.75	50.35	37.36	18.48
2	94	49.55	47.40	34.78	17.04

$$\text{Plastic limit} = \frac{18.48 + 17.04}{2} = 17.76 \simeq 18\%$$

Plasticity index = 23 - 18 = 5%

Observations of test for plastic limit for sample No.18594

Sl. No.	No. of dish	Wt. with wet soil (gm)	Wt. with dry soil (gm)	Wt. of dish (gm)	m.c. (%)
1	119	45.70	43.60	35.47	25.83
2	103	49.05	46.35	36.36	27.03

$$\text{Plastic limit} = \frac{25.83 + 27.03}{2} = 26\%$$

Plasticity index = 39 - 26 = 13%

Appendix-VIII

Observations of direct shear test for sample No.18592

Vertical load	Guage reading	Horizontal load
40	14	23.52
60	26	43.68
80	37	62.16
100	41	68.88

Observations of direct shear test for sample No.18593

Vertical load	Guage reading	Horizontal load
40	10	16.80
60	21	35.28
80	32	53.76
100	37	62.16

Observations of direct shear test for sample No.18594

Vertical load	Guage reading	Horizontal load
40	11	18.48
60	23	38.64
80	25	42.00
100	27	45.36

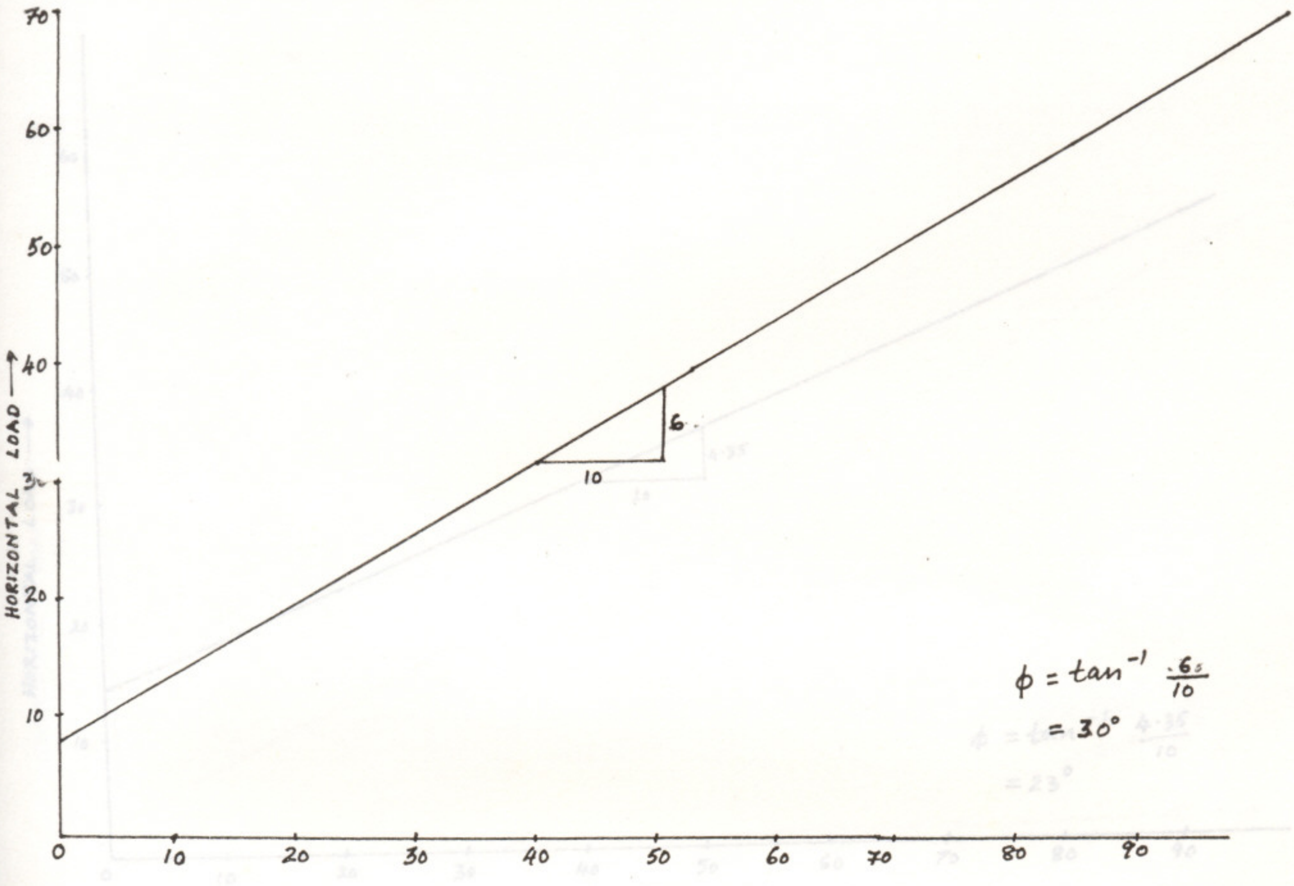

FIG. 19 - DETERMINATION OF ANGLE OF INTERNAL FRICTION ϕ FOR SAMPLE NO. 18592

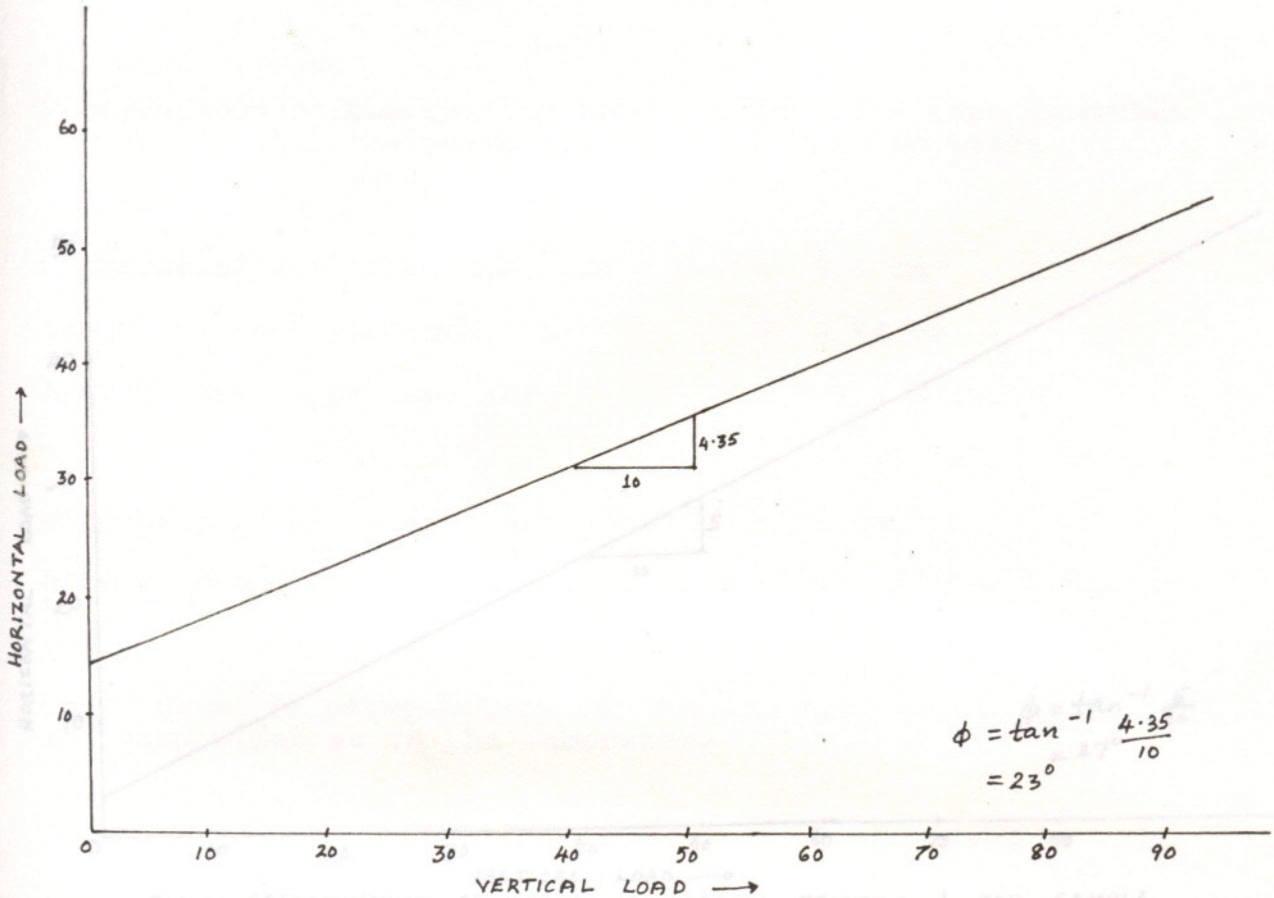

FIG. 20 - DETERMINATION OF ANGLE OF INTERNAL FRICTION φ FOR SAMPLE NO. 18593

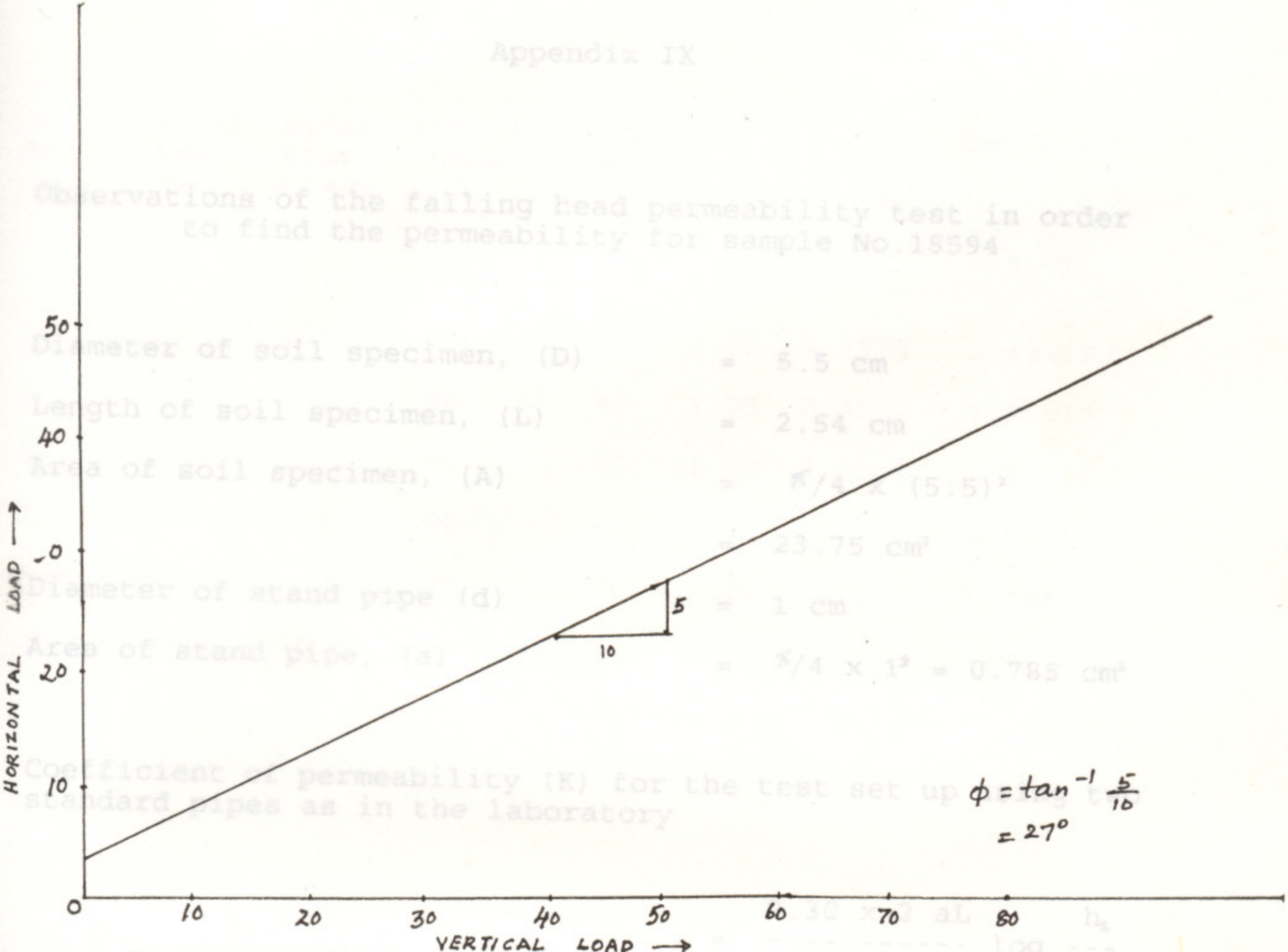

FIG. 21. DETERMINATION OF ANGLE OF INTERNAL FRICTION ϕ FOR SAMPLE NO. 18594

Appendix IX

Observations of the falling head permeability test in order to find the permeability for sample No.18594

Diameter of soil specimen, (D) = 5.5 cm

Length of soil specimen, (L) = 2.54 cm

Area of soil specimen, (A) = $\pi/4 \times (5.5)^2$

= $23.75\ cm^2$

Diameter of stand pipe (d) = 1 cm

Area of stand pipe, (a) = $\pi/4 \times 1^2 = 0.785\ cm^2$

Coefficient of permeability (K) for the test set up using two standard pipes as in the laboratory

$$= \frac{2.30 \times 2\ aL}{At} \log \frac{h_1}{h_2}$$

$$= \frac{2.303 \times 2\ aL}{A}$$

$$= \frac{2.303 \times 2 \times 0.785 \times 2.54}{23.75}$$

$$= 0.3867$$

Temperature of water = 26°C

Height of soil sample above the bottom of scale = 2.03 cm

Sl. No.	Initial time t_1 sec	Final time t_2 sec	Initial head h_1	Final head h_2	$\frac{h_1}{h_2}$	$\log \frac{h_1}{h_2}$	$K = c \frac{\log \frac{h_1}{h_2}}{t_2 - t_1}$
1	0	10320	90	36	2.50	0.3979	1.49×10^{-5}
2	0	7140	90	40	2.25	0.3522	1.91×10^{-5}
3	0	2726	90	50	1.80	0.2553	3.62×10^{-5}
4	0	1401	90	60	1.50	0.1761	4.86×10^{-5}
5	0	705	90	70	1.29	0.1091	5.98×10^{-5}

Average $K = 3.512 \times 10^{-5}$ cm/s

Appendix X

Optimum water content and dry density of fill material by Standard Proctor test

Wt. of mould + wet soil (g)	3990	4105	4195	4215	4180	4160
Wt. of mould (g)	2230	2230	2230	2230	2230	2230
Wt. of soil, W (g)	1660	1775	1865	1885	1850	1830
Volume of mould, V (cc)	863.94	863.94	863.94	863.94	863.94	863.94
Wet density (g/cc)	1.92	2.05	2.16	2.18	2.14	2.12

$$\text{Wet density, } \gamma = \frac{W}{V} = \frac{1660}{863.94} = 1.92 \text{ g/cc}$$

Dish No.	Wt.of dish (gm)	Wt.of dish + wet soil (gm)	Wt.of dish + dry soil (gm)	Wt.of moisture (gm)	Wt.of dry soil (gm)	% of moisture	Av.% of moisture	Dry density
154	36.70	77.30	73.79	3.51	37.09	9.46	9.80	1.75
124	34.77	78.20	74.20	4.00	39.43	10.14		
176	39.60	94.00	88.32	5.68	48.72	11.66	12.28	1.83
139	36.65	100.65	93.34	7.31	56.69	12.89		
	37.15	97.85	90.65	7.20	53.50	13.46	13.29	1.90
186	37.32	95.10	86.40	6.70	51.08	13.12		
37	35.18	97.50	89.11	8.39	53.93	15.51	15.60	1.89
48	36.55	92.00	84.50	7.50	47.95	15.64		
54	36.47	92.30	84.32	7.98	47.85	16.68	17.63	1.82
121	35.09	90.65	81.64	8.71	46.85	18.59		
171	37.84	98.66	89.07	9.54	51.23	18.72	18.72	1.79
96	34.87	88.20	81.55	6.65	46.68	14.26		

Dry density, $\rho_d = \dfrac{\gamma}{1+w} = \dfrac{1.92}{1+0.098} = \dfrac{1.92}{1.098} = 1.748$

$\simeq 1.75$

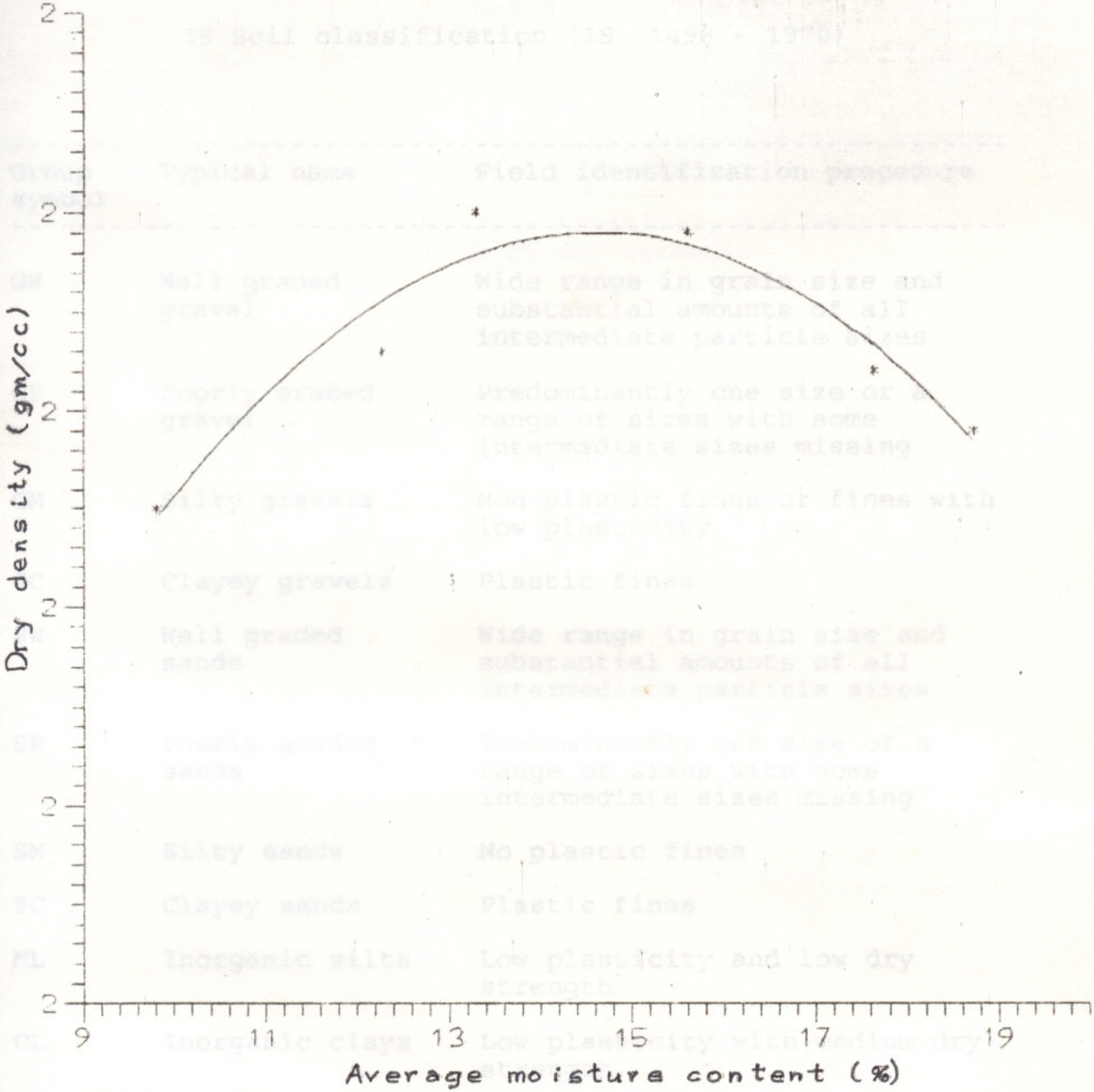

FIG. 22. DETERMINATION OF OPTIMUM MOISTURE CONTENT AND CORRESPONDING DRY DENSITY BY PROCTOR TEST

Appendix-XI

IS Soil classification (IS 1498 - 1970)

Group symbol	Typical name	Field identification procedure
GW	Well graded gravel	Wide range in grain size and substantial amounts of all intermediate particle sizes
GP	Poorly graded gravel	Predominantly one size or a range of sizes with some intermediate sizes missing
GM	Silty gravels	Non-plastic fines or fines with low plasticity
GC	Clayey gravels	Plastic fines
SW	Well graded sands	Wide range in grain size and substantial amounts of all intermediate particle sizes
SP	Poorly graded sands	Predominantly one size of a range of sizes with some intermediate sizes missing
SM	Silty sands	No plastic fines
SC	Clayey sands	Plastic fines
ML	Inorganic silts	Low plasticity and low dry strength
CL	Inorganic clays	Low plasticity with medium dry strength
OL	Organic silts	Low plasticity and low dry strength
MI	Inorganic silts	Medium plasticity and low dry strength
CI	Inorganic clays	Medium plasticity and medium to high dry strength

OI	Organic silts	Medium plasticity with low to medium dry strength
MH	Inorganic silts	High compressibility with low to medium dry strength
CH	Inorganic clays	High plasticity and high to very high dry strength
OH	Organic clays	High plasticity and medium to high dry strength

Appendix-XII

Meteorological parameters of Ponnani Kole

Minimum temperature	=	21°C
Maximum temperature	=	38°C
Mean annual rainfall	=	2757 mm
Bright sunshine hours	=	4 hrs/day - 10 hrs/day
Mean monthly relative humidty	=	85-95%
Maximum wind speed	=	20 km/hr
Mean pan evaporation	=	5.8 mm/day

FEASIBILITY OF A PERMANENT BUND IN THE PONNANI KOLES OF KERALA

By

ABDUL SATHAR, M.

KAREN MARY NIGLI

SAJEENA, S.

ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology in Agricultural Engineering

Faculty of Agricultural Engineering

KERALA AGRICULTURAL UNIVERSITY

Department of Irrigation and Drainage Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573

MALAPPURAM

1996

ABSTRACT

The 'Kole lands" of Kerala comprise of a unique agro-ecologic zone the productivity of rice ranging from 5-8 tonnes per ha. But only one crop can be grown from January to April due to the peculiarity of the area since it lies below sea level and is submerged for most part of the year. This condition can be improved to a second crop if the rice fields are separated from the deep kole by a permanent bund. But it was found that the bunds breached every year at the onset of rains. Keeping this view in mind a detailed study of the soil conditions of the area, possible reasons for frequent breaching of bunds and a modified design of the bund was attempted. The results showed that the fill material has a low permeability value of 3.572×10^{-5} cm/sec at a proctor density of 3.01 g/cc and gives a stable embankment. Modifications to the existing bund were: height 2.91 m, slope angle 45° and top width 2.4 m. Possible reasons for failure were erosion due to high velocity of water, overtopping due to insufficient freeboard and madequate ramming of embankment material. Stone pitching, proper ramming of embankment material at optimum moisture content, sufficient freeboard, placing of a layer of hard material on slopes and tops to prevent frequent breaching is also suggested.