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AN INVESTIGATION OF SLOPE FAILURES IN THE NORTHERN PART OF THAILAND

BY

VISHARN POOPATH

กรมทางหลวง กระทรวงคมนาคม

DEPARTMENT OF HIGHWAYS , MINISTRY OF COMMUNICATIONS ,
BANGKOK 4, THAILAND

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Visharn Poopath B.Eng.(Chula.), M.S., Ph.D. (M.S.U.)

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PREFACE

Construction and maintenance cost of roads in the mountainous area is usually high in comparison with the roads in other conditions. A high percentage of the roads in Thailand are constructed in the typical area since many parts of the country are mountainous, especially the north, and the west. One of the main factors that raise up the costs is the occurance of slope failures during and after the construction. The cause of failure can be due to the lack of knowledge about some special characteristics of the mountains in the local areas. The department of highways is trying to reduce the high expenditure rate by putting more details in the work and, in the consequence, urging more research in this field.

Chaleo Vajrabukka.

(Chaleo Vajrabukka)

Director-General

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IN THE NORTHERN PART OF THAILAND

VICHARN POOPATH, M.S., Ph.D.

CIVIL ENGINEER 6

Materials and Research Div., Department of Highways, Bangkok, Thailand.

1. INTRODUCTION

The paper is a report of a case of slope failures at Km. 42+650 and Km. 44+100 of the road running to the top of Doi Intanont, the highest mountain in the northern part of Thailand. The failures occured at the embankment slope, after the construction. The field investigation was done to find the conditions of terrain, geology, soils, geometry of the existing road at the two stations, possible surface and ground waters, and grassing at the side slopes. The soil samples was tested in laboratory to find its basic properties and strength (direct shear strength). Calculations were done to predict amount of surface water and estimate stability of the slopes. In the final, causes of failure were expected, and the recommendation for correction and the conclusion of the case were drawn.

2. PHYSICAL PROPERTIES OF NATURAL SOIL

Samples of materials were collected at side slope of Km. 45+700. The soil sample is similar to those of the failure area. Field density test was also done at the station. Collected samples were tested in laboratory to find natural moisture content, Atterberg's Limit, gradation, compactability and direct shear strength at various moisture contents of each sample. It was found as presented in the table 1 that the moisture containing naturally in the soil is much higher than the optimum moisture content. This indicates that the moisture in the air will also be high around the area. From the result of the density test, the natural dry density is less than the density at optimum moisture content by about 15 percents. It is expected that the in situ density was decreased by increment of water content due to seepage of surface water into the area. Gradation of the material was found to be composed of about 57 percents of sand size particle and about 43 percents of silt and clay size particles. The 43 percent fine particles which found to be non-plastic are expected to be majorly comoposed of silt-size particles. Soils with the combination of particle sizes is expected to have high permeability and high reduction in strength as subjected to water under unconfined state. Results of the soil strength are presented in Table 1. It was found that the ∅ angle is maximum at a certain moisture content and the c-value decreases as the moisture content increased.

3. GRASSING

Growing of grass was done by cutting the side slope into small steps and the sprigs of grass were grown at a **distance** apart as shown in to Figure 1. The condition of grass growing will be able to slowdown running water on the slope surface and stabilize the soil surface and thus prevents surface scouring, but the slowed down running water will be able to have chance to penetrate down into the side slope since the soil surface is still opened and the running speed is low. At the two

Table 1.

Basic Soil Properties

(Soil sample collected at Km.45+700)

Natural Moisture Content	25.31 %
Optimum Moisture Content	14.45 %
Dry Density at OMC.	1.85 gm/cc.
Natural Dry Density	1.615 " (Field Test)
Natural Wet Density	2.029 " "
Plasticity	non plastic

Gradation:-

Sieve No.	% Finer
3/4"	100
3/8"	98.42
*4	97.3
*10	94.75
*40	67.24
*100	49.49
*200	43.09
Pan	-

Direct Shear Strength

Moisture Content, %	wet, gm/cc	C, Ksm	Ø, degree
19.77	1.83	3179	23
21.06	2.0	2885	35
24.08	1.95	2714	29.5

stations, grassing by this method was done only at the top part, about one third, of the side slopes. The surface of the lower part or the bottom part of the side slopes is a bare soil surface. It should be remarked here that both types of surfaces, the surfaces with and without sprigging of grass, cannot prevent penetration of water through them.

4. CROSS SECTION AND GEOMETRIC ALIGNMENT

Cross sections of the road as designed are shown in Figure 2. It can be seen that at both stations, the road surface slopes down in the opposite direction of the failed side slope. However slope of the shoulder next to the side slope does have the same direction with the side slope. Concrete lining side slope to catch water from the attached hill side and the road surface. At the two stations, the embankments laying on sloping original grounds are about 16 meters high at Km. 42+650 and 21 meters high at Km. 44+100. The side slope of the embankments is 1.25 : 1 which is rather steep for such high embankments. Geometric alignments is a combination of horizontal and vertical curves. The vertical grades are 15 percent at Km. 42+650 and 6.057 percent at Km. 44+100.

5. POSSIBLE SURFACE WATER

Km. 42+650, The surface water that causes failure at the station is expected to come from four separate ways as shown in Figures 3a. Surface water No. (1) which is the rain water on the road surface especially on the area of the shoulder of the road flows down to the slope surface. Surface water No. (2) is the rain water falling directly on the slope surface. Surface water No. (3) is the rain water collected in the side ditch from the hill side sloping to the road and the road surface, and flows down to the toe slope. Water No. (4) is expected to come from the rain water flowing from the right side of the road, and seeps into the road embankment.

Km. 44+100, Only three possible ways of surface water are expected at this station. They are surface water nos. (1),(2) and (3) with the same characteristic as explained in the previous station. It should be remarked here that the surface water No. (3) at this station which is now a running water that comes from the side ditch at the left side of the road and runs across the road in a circular concrete pipe, diameter 0.80 meters was drained out at the right side of the slope by a gutter as shown in the Figure 3b. Unfortunately, at the outlet end of the pipe, the amount of water was too large to be carried by the gutter. Overflow occured at the location. The overflowing water scoured the supporting soil under the gutter and broke a part of the gutter and flowed down perpendicularly to the intended direction to the toe slope.

6. STABILITY ANALYSIS

Stability analysis was done by assuming drained and effective stress condition since the soil is rather permeable and under ground water is not expected. Strength of the soil was obtained from the direct shear test method using the samples collected from the site.. Testing was done to find the soil strength at various moisture contents and densities. The analysis was done to compare stability of the slope at different conditions of moisture containing in the vicinity of sliding zone including the condition which the toe slope is wet. The factor of safety for the various conditions is presented in Table 2. It can be seen that at both stations, the stability of the side slope at natural moisture content is below limit of good stable slope (F.S.=2.00) but not this condition when subjected to softening and scouring of the toe slope by water will tend to cause slippage of soil mass at the side slope along a slip surface. After an initial slippage occured, tension cracks will be formed at the area near the slope crest. The tension crack is always a good indication of soil mass movement and following slip failure.

7. FAILURE EXPECTATION

Assumption of failure of the two stations can be explained as follow. Failure of the side slopes is expected to be mainly due to the instability of the side slope. Surface scouring is also expected to occur at the bare soil surface part of the side slope especially at the toe slope, but the scouring is not the main affect of the slope failure since the scouring will be occured by surface water No.(1) and (2) in which amount of the waters is small in comparison with the surface water No. (3), and a part of the waters will penetrate into the side slope. The instability of the side slope can be easily reached since the slope is rather high and it is not in good stable condition as explained in the section of the stability analysis. Reduction of the slope stability can be caused by reduction of soil strength at toe slope and erosion of soil mass at the area. It is expected that

Table 2.

Km.42+650

Circle No.	C,Kg/m^2	ϕ ,degree	F.S.	Moisture Content
	3179	23	1.945	19.77 %*
1	2885	35	2.22	21.06 %
	2714	29.5	1.95	24.08 %
	3179	23	1.85	19.77 %*
2	2885	35	2.19	21.06 %
	2714	29.5	1.91	24.08 %
			1.73	softened and scoured toe by 3.00 m.

Km.44+100

Circle No.	C,Kg/m^2	ϕ degree	F.S.	Moisture Content
	3179	23	1.625	19.77 %*
1	2885	35	1.925	21.06 %
	2714	29.5	1.675	24.08 %
	3179	23	1.615	19.77 %*
2	2885	35	1.945	21.06 %
	2174	29.5	1.525	24.08 %
			1.46	softened and scoured toe by 4.00 m.

*= Natural Moisture Content.

a part of the waters nos. (1),(2) & (3) percolated into the side slope and were collected at the toe slope, and thus reduce the soil strength at the area. The soil mass at the toe slope can be mainly eroded by surface water No.(3). As the state of instability is reached, movement of a soil mass at the vicinity of the slope will occur along a slip surface and thus causes tension cracks at and near the slope crest as presented in the state I of the Figure 4. Number of cracks are always observed since movement of soil mass always progressived occur. Cracks can also be seen at the road surface. After cracks are formed, a certain amount of waters nos. (1) and (2) can be able to penetrate into the side slope through the cracks. The area is then softened. While the side slope is soft, the seeping water which seeps parallelly to the slope surface will be able to push mass of soil around the cracks down as presented in state II of the Figure 4. After the soft part of the soil at the side slope is pushed away the remaining part will be as shown in the state III. The soil that is pushed to the toe slope will be washed away after ward.

8. RECOMMENDATION FOR CORRECTION

It is quite obvious that the cause of the slope failures at the two stations is the surface water especially the surface water No.(3). To prevent damage from surface water No. (1) and (2) the failed side slope must be refilled with soil aggregate which has rather high plasticity index,e.g. PI. arround 18, and then the compacted side slope must be covered with a layer of clay with grass growing on top of it. If possible a layer of rocks should be placed at bottom of the slope as shown in the Figure 5. To prevent the surface water No. (3) from damaging the slope, a proper gutter must be constructed to drain the water from the side ditch out some where beyond the toe slope. At Km. 44+100, a special size of gutter must be constructed at the end of the outlet pipe to prevent overflowing of water at the location.

9. CONCLUSION

It is concluded here that :-

1. Failures of side slope at Km. 42+680 and 44+100 occured around the area of decomposed rocks of high degree of weathering.

2. The weathered rocks which is soil after cut off, compose mainly of sand and silt size particles and thus gives high permeability and it is softened as subjected to water.

3. Grassing by the method of sprigging can only stiffen the soil surface but can not prevent water from penetrating through the soil surface.

4. Failure of the side slopes is expected to be initiated by movement of the soil mass due to instability of the slope as collection of water at and scouring of the toe slope occur, and then the whole side slope is softened by penetrating water through the tension cracks formed after the soil mass movement. The softened soil will be then pushed down by the seeping water.

5. The two cases of slope failure will not be as the existing shape if only surface scouring took place. The failures are mainly due to instability of the slope in the first place.

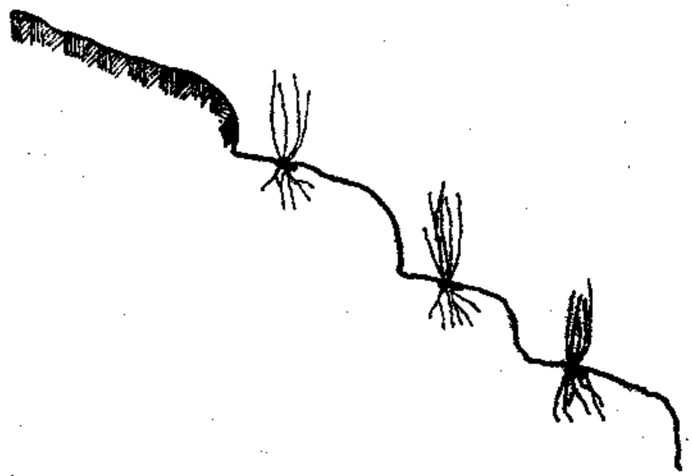

FIG. 1. GRASS GROWING CONDITION

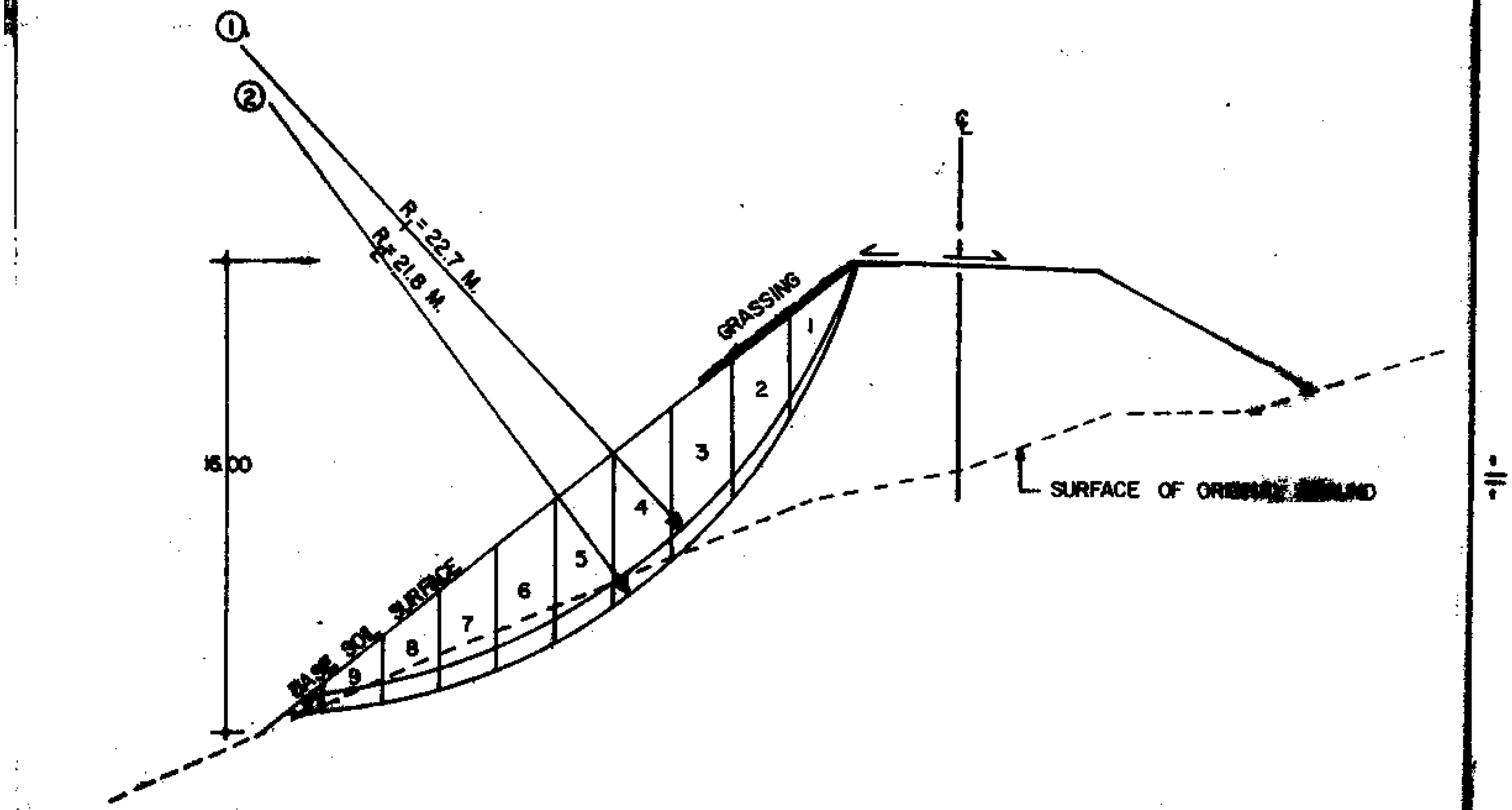

FIG. 2 a. CROSS SECTION, K.M. 42+650

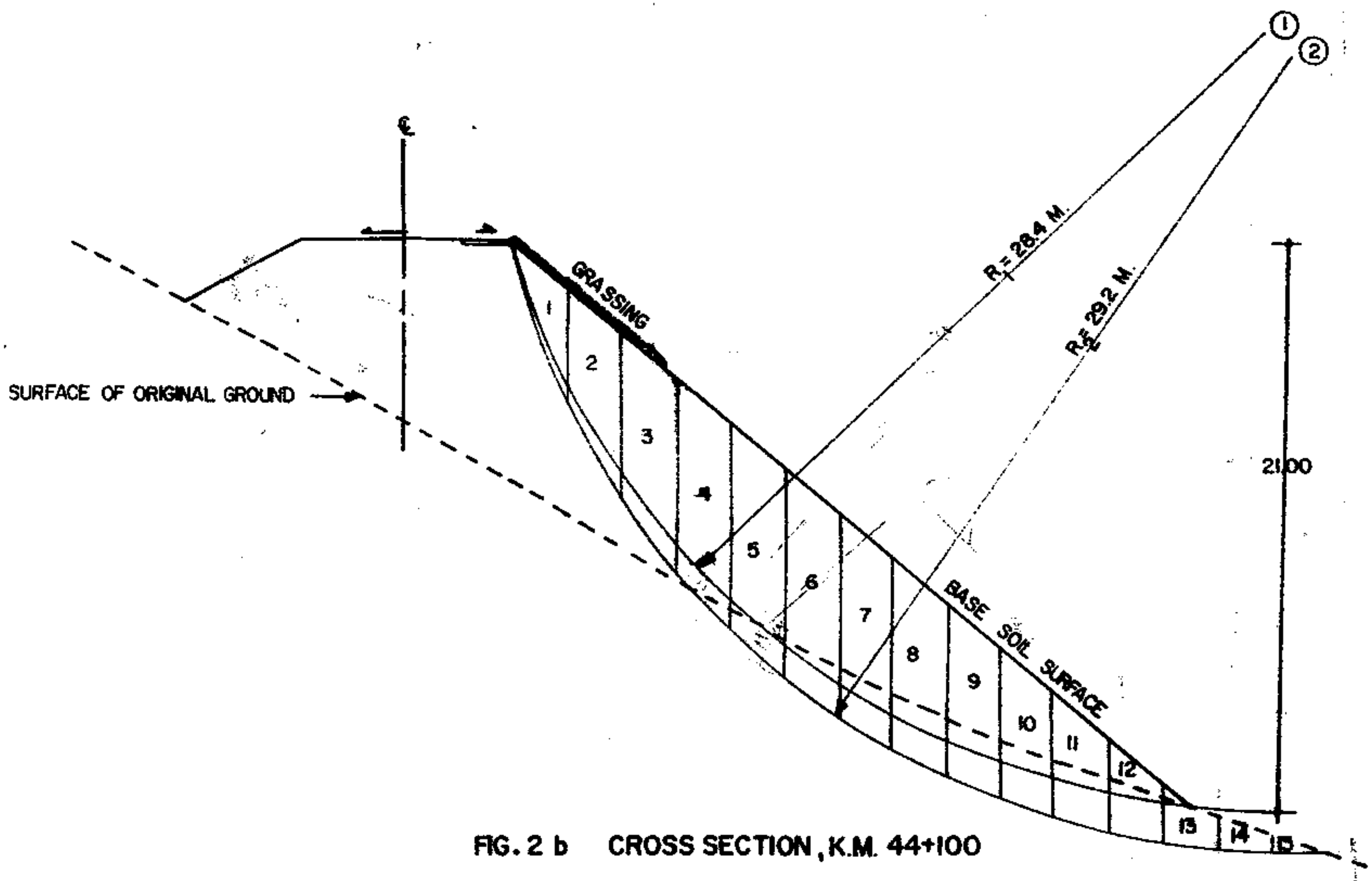

FIG. 2 b CROSS SECTION, K.M. 44+100

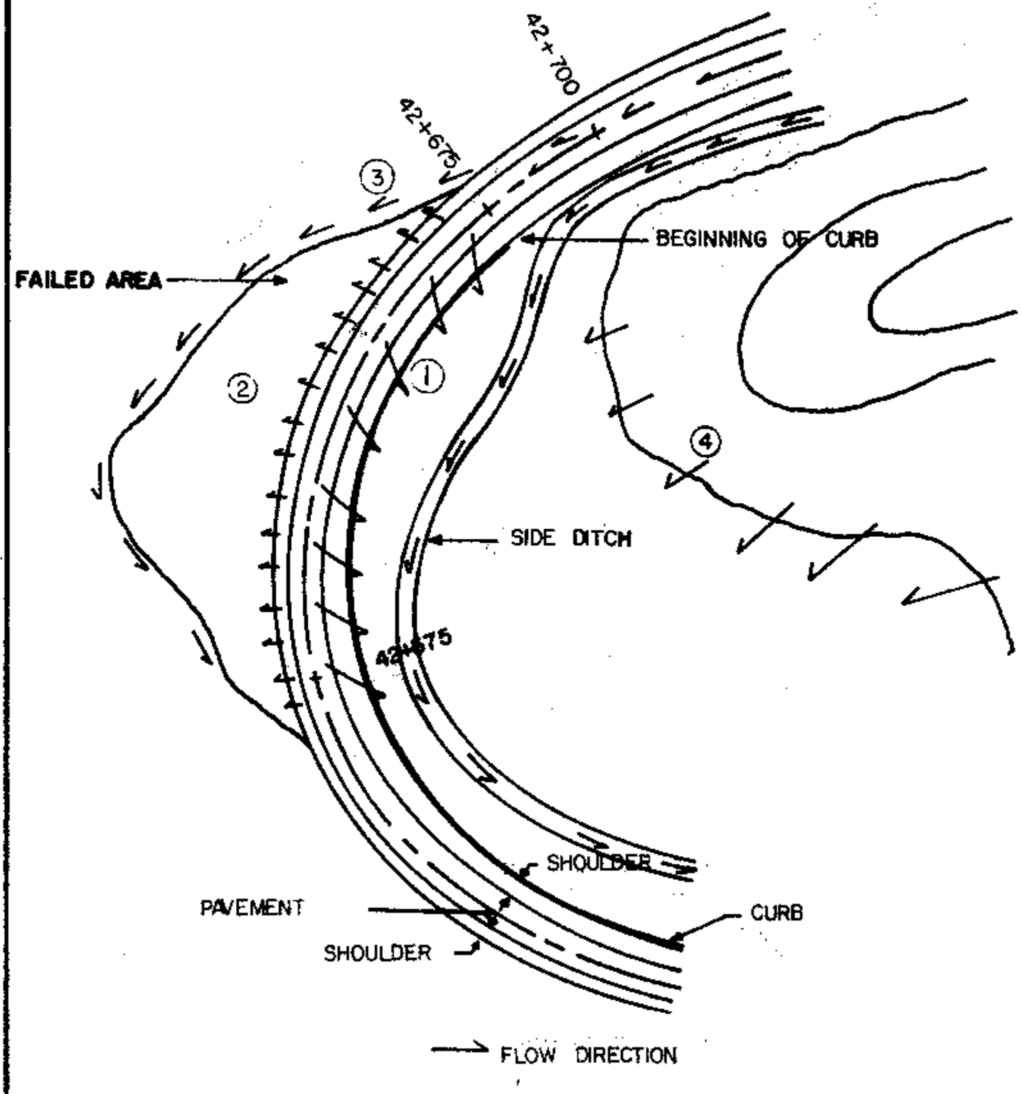

FIG. 3 a TOP VIEW- POSSIBLE SURFACE WATER (K.M. 42+650)

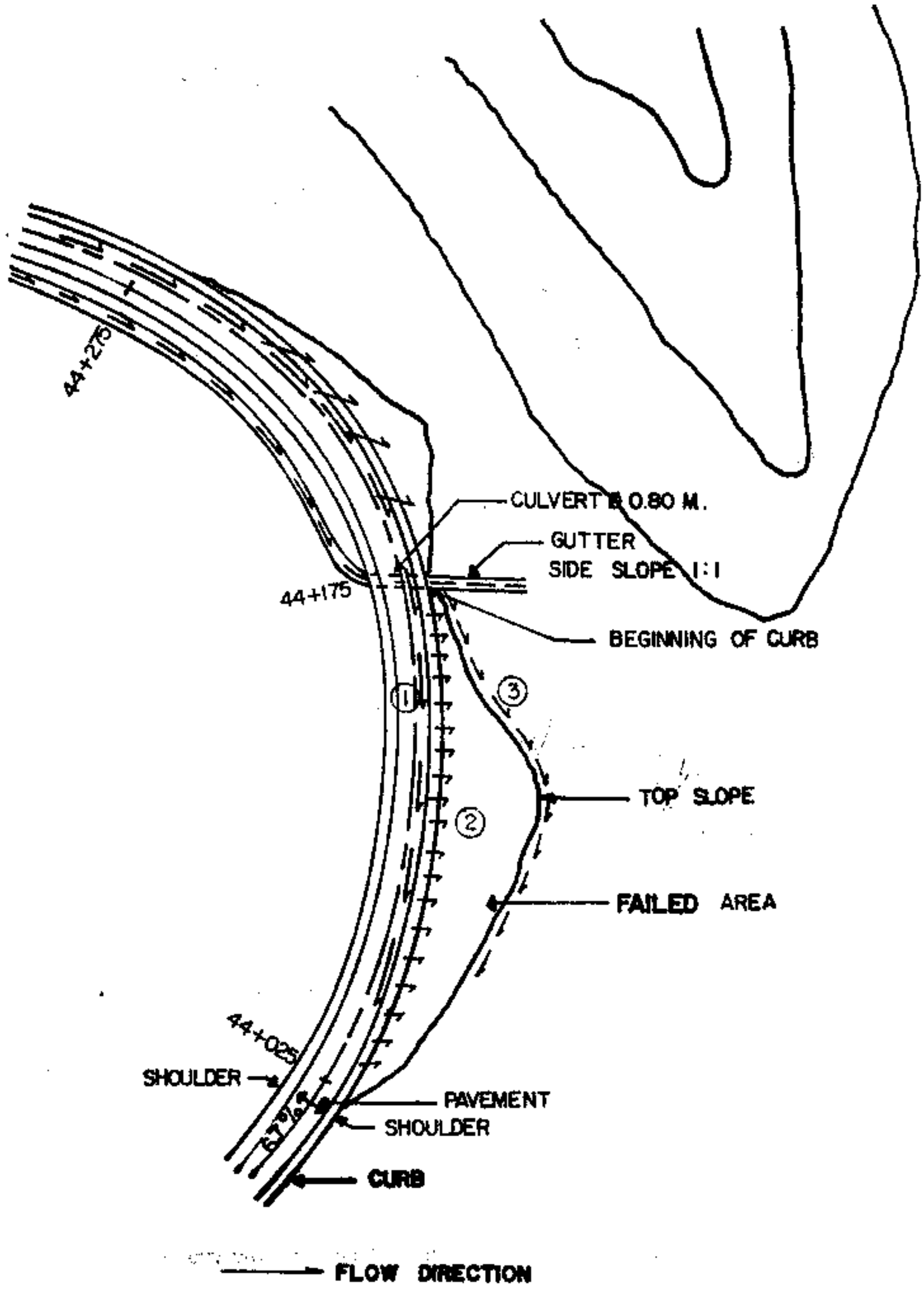

FIG. 3 b POSSIBLE SURFACE WATER (K.M. 44 + 100)

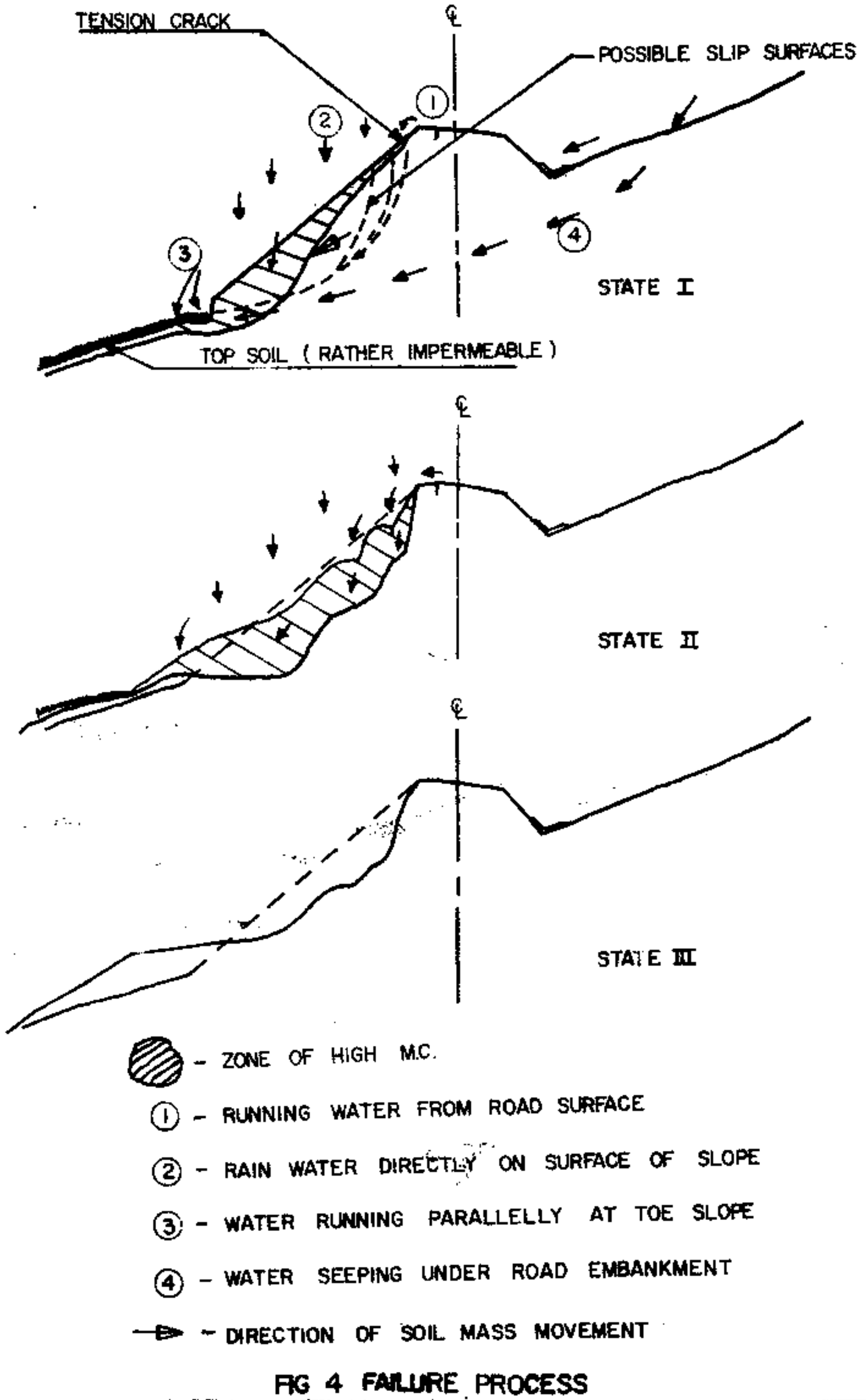

FIG 4 FAILURE PROCESS

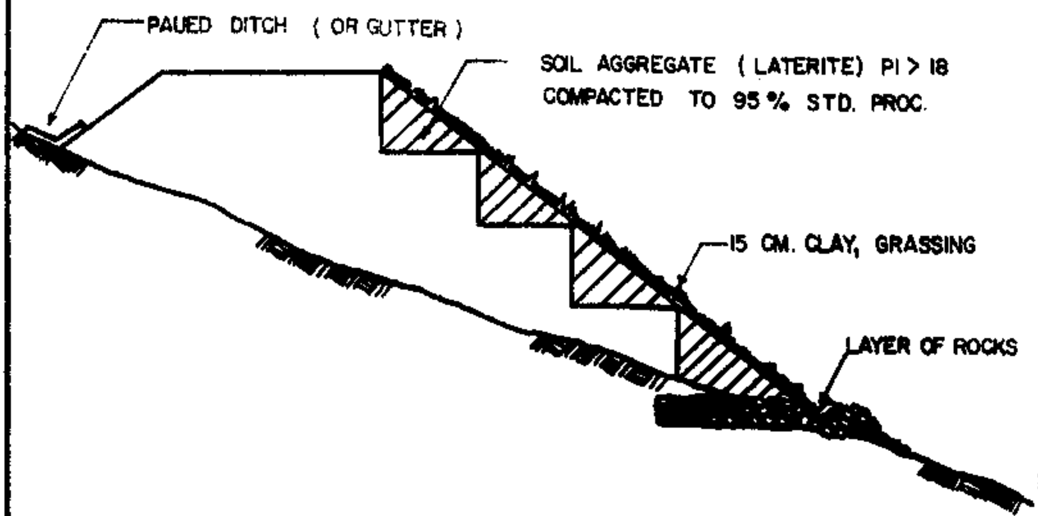
PAUED DITCH (OR GUTTER)
SOIL AGGREGATE (LATERITE) PI > 18
COMPACTED TO 95 % STD. PROC.
15 CM. CLAY, GRASSING
LAYER OF ROCKS

FIG. 5

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