

การศึกษาการวิบัติของดินถมกันทางซึ่งก่อสร้างบนเสบกินเชิงเขา
บริเวณทางหลวง สาย ปราชินบุรี - เขาใหญ่ ก.ม. 12.658 ถึง 12.765

นาย สุรพล สวงแก้ว



วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาคามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

ภาควิชาธรณีวิทยา

บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย

พ.ศ. 2532

ISBN 974-569-932-2

ลิขสิทธิ์ของบัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย

015364

T 1740662

A SLOPE FAILURE INVESTIGATION OF THE EMBANKMENT
ON THE COLLUVIAL SOIL BETWEEN KM. 12.658 AND
12.765 PRACHINBURI TO KHAO YAI HIGHWAY

Mr. Surapol Sanguankeol

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science

Department of Geology

Graduate School

Chulalongkorn University

1989

ISBN 974-569-932-2

Copyright of the Graduate School, Chulalongkorn University

Thesis title A Slope Failure Investigation of the
 Embankment on the Colluvial Soil Between
 KM. 12.658 and 12.765 Prachinburi to
 Khao Yai Highway
By Mr. Surapol Sanguankeo
Department Geology
Thesis advisor Nopadon Muangnoicharoen, Ph.D.
Thesis co-advisor Niyom Deeswasmongkol, Ph.D.

Accepted by the Graduate School, Chulalongkorn
University in Partial Fulfillment of the Requirement for
Master's Degree.

Thavorn Vajrabhaya
..... Dean of Graduate School
(Professor Thavorn Vajrabhaya, Ph.D.)

Thesis committee

Ch. Khantap
..... Chairman
(Chaiyudh Khantaprab, Ph.D.)

N. Muangnoich
..... Thesis advisor
(Nopadon Muangnoicharoen, Ph.D.)

Niyom
..... Thesis co-advisor
(Niyom Deeswasmongkol, Ph.D.)

Pichit Jammongpipatkul
..... Member
(Pichit Jammongpipatkul, Ph.D.)



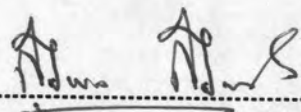
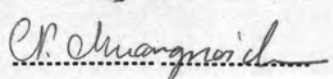
พิมพ์ต้นฉบับบทคัดย่อวิทยานิพนธ์ภายในกรอบสี่เหลี่ยมนี้เพียงแผ่นเดียว

สรุปผล สงวนแก้ว : การศึกษาการวิบัติของดินถมคันทางซึ่งก่อสร้างบนเศษหินเชิงเขา บริเวณทางหลวง สาย ปราจีนบุรี-เขาใหญ่ ก.ม. 12.658 ถึง 12.765 (A SLOPE FAILURE INVESTIGATION OF THE EMBANKMENT ON THE COLLUVIAL SOIL BETWEEN KM. 12.658 AND 12.765 PRACHINBURI TO KHAO YAI HIGHWAY.) อ.ที่ปรึกษา : รศ.ดร. นภค ม่วงน้อยเจริญ, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม : ดร.นิยม ดีสวัสดิ์มงคล, 211 หน้า.

การศึกษากระทำที่ทางหลวงสาย ปราจีนบุรี-เขาใหญ่ (3077) ระหว่าง ก.ม.ที่ 11 ถึง 15.3 ซึ่งวางตัวอยู่บนลาดเศษหินเชิงเขาและได้เกิดการวิบัติของดินถมคันทางในช่วง ก.ม. 12.658 ถึง 12.765 ขึ้น ซ้ำแล้วซ้ำอีกถึง 3 ครั้ง ในปี พ.ศ. 2524, 2526 และ 2528/2529

การศึกษากระทำโดยการสำรวจเบื้องต้น แล้วจึงศึกษาในรายละเอียดทางด้านธรณีวิทยา, ธรณีเทคนิค, ธรณีสัณฐานวิทยา และ อุทกวิทยา เพื่อวิเคราะห์และประเมินหาเสถียรภาพและสาเหตุของการวิบัติของคันทางที่ก่อสร้างบนลาดเศษหินเชิงเขาบริเวณนี้ การวิเคราะห์หาเสถียรภาพของเชิงลาดได้ทำการ โดยวิธีขอบเขตสมดุล ในลักษณะที่เป็นแรงประสิทธิผลและได้ทำการแบ่งการวิเคราะห์เสถียรภาพออกเป็น 3 ระยะ คือ เสถียรภาพก่อนการก่อสร้าง, เสถียรภาพของการวิบัติของคันทาง ที่เกิดขึ้นในปี พ.ศ. 2526 และระหว่าง พ.ศ. 2528-2529 การวิเคราะห์เสถียรภาพของเชิงลาดนี้ ได้กระทำโดยใช้วิธีหลากหลายทำให้เกิดรูปแบบของการวิบัติที่แตกต่างกัน และนำมาเปรียบเทียบผลที่ได้จากวิธีการวิเคราะห์ต่าง ๆ นี้ ผลจากการศึกษาในครั้งนี้แสดงให้เห็นว่าการวิบัติเกิดขึ้นเนื่องจากตัวคันทางถูกก่อสร้างคร่อมอยู่บนแนวผาชันของแผ่นดินถล่มในธรรมชาติที่ยังคงมีการเคลื่อนตัวอยู่ โดยมีลักษณะการวิบัติเป็นแบบเกิดลูกกลมในมวลของ เศษหินเชิง เขาแห่งนี้

ภาควิชา ธรณีวิทยา
สาขาวิชา ธรณีวิทยา
ปีการศึกษา 2532

ลายมือชื่อนิติ 
ลายมือชื่ออาจารย์ที่ปรึกษา 

พิมพ์ต้นฉบับบทคัดย่อวิทยานิพนธ์ภายในกรอบสี่เหลี่ยมนี้เพียงแผ่นเดียว

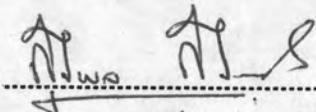
v

SURAPOL SANGUANKEO : A SLOPE FAILURE INVESTIGATION OF THE EMBANKMENT ON THE COLLUVIAL SOIL BETWEEN KM. 12.658 AND 12.765 PRACHINBURI TO KHAO YAI HIGHWAY. THESIS ADVISOR : ASSO. PROF. NOPADON MUANGNOICHA-ROEN, Ph.D., THESIS CO-ADVISOR : NIYOM DEESWASMONGKOL, Ph.D., Ed.D. 211 PP.

This study was done on the Prachinburi-Khao Yai Highway (3077) between KM. 11 and KM. 15.3 where it passes through a colluvial slope. Between KMs. 12.658 and 12.765, the foundation failures has occurred repeatedly on this embankment three times in 1981, 1983 and 1985/1986.

The reconnaissance and detailed geologic, geotechnic, geomorphologic and hydrologic investigations were done to analyze and evaluate the stability and causes of failures of the embankment on the colluvial slope. The slope stability was analyzed in terms of effective stress by limit equilibrium and categorized into 3 stages, namely the preconstruction stage, the stages of embankment failures in 1983 and in 1985/1986. Different mode of failures were thus recommended and compared. The results of the investigations revealed that the failures occurred as the embankment was built on the active natural landslide scarp which indicates a progressive failure in the colluvial mass.

ภาควิชา ธรณีวิทยา
สาขาวิชา ธรณีวิทยา
ปีการศึกษา 2532

ลายมือชื่อนิสิต 
ลายมือชื่ออาจารย์ที่ปรึกษา 

ACKNOWLEDGEMENTS

The author wishes to express his most sincere gratitude to his thesis advisors, Dr. Nopadon Muangnoicharoen and Dr. Niyom Deeswasmongkol, for their encouragements and valuable guidances throughout his study. He also wishes to express his thanks to Dr. Chaiyudh Khantaprab and Dr. Pichit Jammongpipatkul for serving as members of the examination committee.

The author is also grateful to the following persons and organizations for helping to make this study possible:

Mr. Sathean Wongvichien and Mr. Chinchai Mahasaen of the Department of Highways (DOH) for permitting the author to study at the Graduate School Chulalongkorn University, Dr. Teerachart Ruenkraitersa and Dr. Pichit Jammongpipatkul of the Materials and Researches Division, DOH for their valuable suggestions. Dr. Narong Thiramongkol for valuable suggestions on geomorphology study. Mr. Somchai Kokhamhaeng, Mr. Somchai Plangpongpun, Mr. Wisan Tandicul for their valuable suggestions on the computer programs. Mr. Boonchai Chitplee and office staff of Prachinburi District Highway for their arrangement for residence, equipments and kind assistance. Mr. Suwat Pholsin for suggestion and guidance on the resistivity survey. Mr. Thiva Supajanya for the computer used in typing the manuscripts.

The office staff of the Geology Department Chulalongkorn University for their kind and friendly cooperation of this study.

The financial support of his study was partially provided by the Chulalongkorn-Amoco Geological Fund, and the Graduate School Fund of the Chulalongkorn University.

Finally, this thesis is dedicated to his parents and wife for the enduring patience, support, and encouragement they have given to help pursue the objective of his study.

CONTENTS

	Page
ABSTRACT IN THAI	iv
ABSTRACT IN ENGLISH	v
ACKNOWLEDGEMENTS	vi
LIST OF TABLES.....	xiv
LIST OF FIGURES.....	xv
LIST OF PLATES	xx
LIST OF ABBREVIATIONS AND SYMBOLS	xxi
CHAPTER	1
I INTRODUCTION	1
1.1 Purpose and Scope	1
1.2 Location and Accessibility	2
1.3 Approach to Study	2
1.3.1 Geologic investigation	2
1.3.1.1 Field geologic investigation	2
1.3.1.2 Geomorphologic investigation	4
1.3.1.3 Geophysical investigation ..	4
1.3.2 Geotechnical and hydrologic	
investigation	4
1.3.2.1 Field geotechnical	
investigation.....	4
1.3.2.2 Hydrologic investigation....	5
1.3.2.3 Laboratory tests	5
1.3.3 Compilation of geologic and	
geotechnical data.....	5

	Page
1.3.4 Slope stability analysis.....	5
1.4 Climate and Vegetation	11
1.5 Previous Work	11
II HISTORY OF SLOPE FAILURE	12
2.1 First Failure in 1981	12
2.1.1 History of failure	12
2.1.2 Remedial measures	12
2.2 Second Failure in 1983	14
2.2.1 History of failure	14
2.2.2 Nature and type of failure.....	14
2.2.3 Movement of failure.....	14
2.2.4 Remedial measures	18
2.3 Third Failure in 1985-1986	18
2.3.1 History of failure	18
2.3.2 Nature and type of failure	18
2.3.3 Movement of failure	24
III GEOLOGY OF THE STUDY AREA	31
3.1 Regional Geology	31
3.2 Areal Geology	33
3.2.1 Rock units and stratigraphy	33
3.2.2 Geologic structure	34
IV GEOMORPHOLOGY INVESTIGATION	38
4.1 Air-Photographic Interpretation	38
4.2 Geomorphology Investigation along Prachinburi- Khao Yai Area	41

	Page
4.2.1 Units of fluvial origin	42
4.2.2 Units of gravitative origin	44
4.2.3 Units of marine origin	44
4.2.4 Units of erosional origin	44
4.2.5 Unit of structural origin	45
4.3 Detailed Geomorphology Investigation of the Study Area of Embankment Failure	45
V GEOPHYSICAL INVESTIGATION	52
5.1 Theoretical Background of Resistivity Method	52
5.2 Electrical Resistivity Survey in the Present Study	53
5.2.1 Procedure of resistivity survey	54
5.2.2 Interpretation of a resistivity survey results	55
5.2.2.1 Method of interpretation ...	55
5.2.2.2 Result of interpretation	55
VI GEOTECHNICAL INVESTIGATION	62
6.1 Regional Geotechnical Investigation along the Prachinburi - Khao Yai Area	63
6.1.1 Method of investigation	63
6.1.2 The classification and nomenclature of rocks and soils units	64
6.1.2.1 Surficial deposits	64
6.1.2.2 Duricrust deposits	65
6.1.2.3 Rock units	66

	Page
6.2 Local Geotechnical Investigation of the Study Area of Embankment Failure	66
6.2.1 Surface investigation	67
6.2.1.1 Detailed topographic map ...	67
6.2.1.2 Profiles	67
6.2.1.3 Engineering geological map of study area of embankment failure	67
6.2.2 Subsurface investigation	67
6.2.2.1 Boring	67
6.2.2.2 Simple sounding penetration test	71
6.2.2.3 Test pits	74
6.2.3 The interpretation results of local geotechnical investigation	74
6.2.4 In-situ shear strength test of soils.	76
6.2.4.1 Standard Penetration Test ..	76
6.2.5 Soil sampling methods	78
6.2.5.1 Sampling and type of samples	79
VII HYDROLOGICAL INVESTIGATION	81
7.1 Meteorological Study	81
7.2 Surface Water Investigation	81
7.3 Spring and Seepages Investigation	84
7.4 Groundwater Investigation	84
7.5 Field Permeability Test	86

	Page
VIII LABORATORY TESTS	90
8.1 Tests on Engineering Properties of Soils ...	90
8.1.1 Water content determination	90
8.1.2 Specific gravity determination	91
8.1.3 Atterberg limits	92
8.1.4 Grain - size distribution of soils ..	94
8.1.5 California Bearing Ratio test of filled material,.....	97
8.1.6 Standard compaction test	97
8.1.7 Direct shear test	100
8.1.7.1 Measurement of residual strength in laboratory	102
8.1.7.2 Determination of residual and peak strength of soil for stability analysis	104
8.2 Engineering Classification of Soils	112
8.3 Mineralogical Identification of soils	113
IX BACK ANALYSIS	117
9.1 Slope Stability Analysis of the Study Area ..	117
9.1.1 Analysis of failure for preconstruction stage.....	119
9.1.2 Analysis of failure for 1985 failure	120
9.1.3 Analysis of failure for 1985-1986 failure	127

	Page
9.2 Sensitivity Analyses	128
9.2.1 Sensitivity analyses for failure in 1983	133
9.2.2 Sensitivity analyses for failure in 1985 - 1986	133
X CONCLUSIONS	136
XI SUGGESTIONS	139
REFERENCES	142
APPENDIX A	148
APPENDIX B	160
APPENDIX C	168
APPENDIX D	176
APPENDIX E	179
APPENDIX F	198
APPENDIX G	203
BIOGRAPHY	211

LIST OF TABLES

Table		Page
5.1	Summary of the results of interpretation of electrical resistivity sounding	58
7.1	Summary of the coefficient of permeability test in filled material and colluvium	89
8.1	Results of the natural and saturated water content of soils	91
8.2	Results of the specific gravity test of soils	91
8.3	Results of Atterberg limits	92
8.4	Potential expansiveness of soils	93
8.5	Summary of direct shear test results	111
8.6	Results of soils classification	113
8.7	Summary of the test results of soils	116
9.1	Factor of safety for different groundwater surface, for failure in 1983	133
9.2	Factor of safety for different groundwater levels, for failure in 1985 -1986	134
D-1	Soil ratings for roads and runways	177
D-2	General guide to selection of soils on basis of anticipated embankment performance.	177
D-3	Compaction characteristics and ratings of soils	178

LIST OF FIGURES

Figure		Page
1.1	Location of the study area	3
1.2	Flow charts of methods of study	6
2.1	First failure on the embankment and box culvert between KMs. 12.650 and 12.750 in 1981	13
2.2	Second failure on the bridge and bridge approached abutment between KM. 12.696 and KM. 12.745	15
2.3	A cross-section parallel to road center line for failure in 1983	17
2.4	Remedial measures of second failure in 1983	19
2.5	Initial failure of embankment in August, 1985	20
2.6	Failure of embankment in August, 1986	22
2.7	Major cracks of failure in 1985-1986	25
2.8	Major cracks of failure in 1985	25
2.9	Vertical displacement at the major scarp, in 1986	26
2.10	Tension cracks in the colluvial slope near the toe of the embankment	27
2.11	The fresh soil movement in the colluvial slope	28

Figure		Page
2.12	Fresh soil movement at the natural landslide scarp	29
2.13	Progressive of tension cracks at upslope area	30
3.1	Regional geological map of the study area .	32
3.2	Khao Yai volcanic rocks cropped out at the toe of colluvial slope	36
3.3	Outcrop of mudstone and siltstone of Phu Kradung formation in the study area ...	36
3.4	The colluvial deposit in the study area....	37
4.1	Aerial photograph-interpretation map of the study area of embankment failures	40
4.2	Geomorphological map of Prachinburi - Khao Yai area	43
4.3	Scenery of the study area of embankment failures	48
4.4	Diagrammatic representation of the hypothetical nine unit landsurface model ..	49
4.5	Cross-section of the natural slope in the study area of embankment failure.....	50
4.6	Gentle slope of colluvial deposit	51
5.1	Schlumberger's configuration	53
6.1	Engineering geological map of the slide area (1983)	69

Figure		Page
6.2	Location of drilled holes for subsurface investigation of failure in 1983	70
6.3	Simple sounding penetration setup	72
6.4	Examination of soil layers by simple penetration test in the landslide area	73
6.5	Standard Penetration Test equipment	77
6.6	The collection of undisturbed box sample ..	80
7.1	Record of rainfall in Prachinburi	82
7.2	Original topographic detailed of study area of embankment failure	83
7.3	Open-end test for permeability in the field	87
8.1	The grain-size distribution test results of 1983 filled material	95
8.2	The grain-size distribution test results of 1985 - 1986 filled material	96
8.3	The grain-size distribution test results of colluvial soil	98
8.4	The grain-size distribution test results of shear zone soil	99
8.5	Standard compaction curves for filled materials	101
8.6	Approximate relationship between the drained angle of residual resistance and the plasticity index	106
8.7	Direct shear test on 1983 filled material .	107

Figure		Page
8.8	Direct shear test on 1985 - 1986 filled material	108
8.9	Direct shear test on colluvial soil.....	109
8.10	Repeat cycle direct shear test on undisturbed sample of shear zone soil.....	110
8.11	The plots of liquid limits versus plastic limit	114
8.12	X-ray diffractogram of the shear zone soil .	115
9.1	Natural landslide scars of the embankment failure area	118
9.2	Stability analysis by the wedge method for preconstruction stage.....	121
9.3	Summary of the stability analysis results by Janbu's method	122
9.4	Stability analysis by the wedge method for failure in 1983	124
9.5	Summary of the stability analysis results by Janbu's method for failure in 1983	125
9.6	Section of slope failure in 1983, showing different critical failure surfaces and theirs F.S.....	126
9.7	Stability analysis by wedge method for failure in 1985 - 1986	129
9.8	Summary of the stability analysis results by Janbu's method for failure in 1985-1986 .	130

Figure		Page
9.9	Summary of the stability analysis results by Janbu's method for failure in 1985-1986 .	131
9.10	Section of slope failure in 1985-1986, showing different critical failure surfaces and theirs F.S.	132
9.11	Variation of factor of safety to the depth to groundwater.....	135
C-1	Field electrical resistivity curves and its interpretation	169
E-1	Forces involved in effective stress slip circle analysis	180
E-2	Sliding block or wedge method	184
E-3	Morgenstern and Price method	186
E-4	Janbu method	190
E-5a	Stability analysis by Janbu routine method	194
E-5b	Determination of value of n_{α}	195
E-5c	Determination of value of n_{α}	196
F-1	Common types of slides in colluvium	201
G-1	Tabular form for calculating factor of safety by wedge method for preconstruction stage	204
G-2	Tabular form for calculating factor of safety by wedge method for failure in 1983	205
G-3	Tabular form for calculating factor of safety by wedge method for failure in 1985-1986	206

LIST OF PLATES

Plate

- 6.1 Geotechnical map of Prachinburi - Khao Yai
area
- 6.2 Engineering geological map of landslide
area, for failure in 1985 -1986

ABBREVIATION AND SYMBOLS

ASTM	American Society for Testing and Materials
col	colluvium
c'	cohesion intercept, in term of effective stress
c'_r	residual cohesion intercept, in term of effective stress
c'_{m_1}	mobilized cohesion in term of effective stress (wedge no.1)
c'_{m_2}	mobilized cohesion in term of effective stress (wedge no.2)
c'_{m_3}	mobilized cohesion in term of effective stress (wedge no3)
$E_{1,2}$	side force between wedge no.1 and 2
$E_{2,3}$	side force between wedge no.2 and 3
F.S.	factor of safety
G.W.S.	groundwater surface
G.W.L.	groundwater level
R_1	resultant force of normal and shear force on the base of wedge no.1
R_2	resultant force of normal and shear force on the base of wedge no.2
R_3	resultant force of normal and shear force on the base of wedge no.3
R_s	residual soil
S_r	residual shear strength
h_1	thickness of first layer

h_2	thickness of second layer
h_3	thickness of third layer
U	pore water pressure
W_1	weight of wedge no.1
W_2	weight of wedge no.2
W_3	weight of wedge no.3
α	angle of shear surface
σ'	effective normal stress
τ	shear stress
ϕ	angle of internal friction, in general
ϕ'_r	angle of residual shearing resistance in term of effective stress
ϕ'_{m1}	mobilized friction angle in term of effective stress(wedge no.1)
ϕ'_{m2}	mobilized friction angle in term of effective stress(wedge no.2)
ϕ'_{m3}	mobilized friction angle in term of effective stress(wedge no.3)
$\tan \phi'$	friction coefficient on effective stress basis
ρ_1	the resistivity of first layer
ρ_2	the resistivity of second layer
ρ_3	the resistivity of third layer
ρ_a	apparent resistivity