LARGE SCALE DIRECT SHEAR TESTING OF COMPACTED WASTE ROCKS FROM MAE TAN LIGNITE MINE

Thongchai Boonklung

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

Suranaree University of Technology

Academic Year 2013

การทดสอบแรงเฉือนโดยตรงขนาดใหญ่ของเศษหินบดอัดจากเหมืองลิกไนท์แม่ทาน

นายธงชัย บุญกลึง

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาวิศวกรรมโยธา
มหาวิทยาลัยเทคโนโลยีสุรนารี
ปีการศึกษา 2556

LARGE SCALE DIRECT SHEAR TESTING OF COMPACTED WASTE ROCKS FROM MAE TAN LIGNITE MINE

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for a Master's Degree.

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การทดสอบแรงเฉือนโดยตรงขนาดใหญ่ได้ดำเนินการทดสอบโดยตัวอย่างหินผุของหินทรายแป้งและหินโคลนที่วางอยู่บนชั้นถ่านหินที่เหมืองถ่านหินแม่ทานจังหวัดลำปาง วัตถุประสงค์หลักเพื่อทำการหาพารามิเตอร์กำลังรับแรงเฉือนของวัสดุที่มีขนาดใหญ่กว่า 4.75 มิลลิเมตรซึ่งไม่สามารถทำการทดสอบด้วยกล่องทดสอบแรงเฉือนโดยทั่วไปได้ วิธีการทดสอบได้อ้างอิงตามมาตรฐาน ASTM พารามิเตอร์ของกำลังรับแรงเฉือนของขนาดเม็ดดินที่ใหญ่กว่า 4.75 มิลลิเมตรมีความสำคัญในการวิเคราะห์และออกแบบเสถียรภาพของคันดินเพื่อทำการฟื้นฟูสภาพแวดล้อมของเหมือง การถมกลับของคันดินมีความสูงกว่า 200 เมตรซึ่งต้องทำการบดอัดสำหรับเสถียรภาพของคันดินในระยะยาวหลังจากสิ้นสุดสัมปทานเหมือง การดำเนินงานวิจัยประกอบด้วย (1) การเก็บตัวอย่างหินผุในสนาม (2) สร้างกล่องทดสอบแรงเฉือนขนาดใหญ่ที่มีขนาดเส้นผ่านศูนย์กลาง 7.5 นิ้วในห้องปฏิบัติการสำหรับทดสอบตัวอย่างขนาดร่อนผ่านตะแกรงขนาดช่องเปิด ¾ นิ้ว (3) ดำเนินการทดสอบการทดสอบแรงเฉือนโดยตรงขนาดเล็กและขนาดใหญ่โดยทำการบดอัดตัวอย่างภายใต้การแปรผันปริมาณความชื้นตั้งแต่ 2% ถึง 15% และใช้หน่วยแรงตั้งฉากจาก 351.50 กิโลนิวตันต่อตารางเมตรถึง 1406.02 กิโลนิวตันต่อตารางเมตร (4) ทำการคำนวณหากำลังรับแรงเฉือนของวัสดุจากการแปรผันปริมาณความชื้น (5) ดำเนินการวิเคราะห์โดยระเบียบวิธีเชิงตัวเลขโดยใช้วิธีไฟไนต์ดิฟเฟอร์เร็น FLAC 2D เพื่อทำการหาเสถียรภาพของคันดินบดอัด ผลการดำเนินการทดสอบแรงเฉือนโดยตรงพบว่าขนาดของตัวอย่าง ปริมาณความชื้น ขนาดของกล่องทดสอบและความหนาแน่นมีผลกระทบต่อแรงเฉือนของดินบดอัด มุมเสียดทานมีค่าลดลงเมื่อปริมาณความชื้นเพิ่มขึ้น มุมเสียดทานที่มีขนาดดินเม็ดใหญ่สะสมมีค่ามุมเสียดทานสูง ในการทดสอบแรงเฉือนโดยตรงของกล่องทดสอบแรงเฉือนขนาดใหญ่มุมเสียดทานของดินที่มีขนาดเม็ดดินใหญ่กว่า 4.75 มิลลิเมตรปนมีค่าสูงกว่าเม็ดดินที่ไม่มีปริมาณดังกล่าวเล็กน้อย แรงยึดเกาะกันของดินมีค่าสูงสุดใกล้กับจุดปริมาณความชื้นเหมาะสมสำหรับกล่องทดสอบแรงเฉือนขนาดใหญ่และมีค่าลดลงเมื่อปริมาณความชื้นเพิ่มขึ้นสำหรับกล่องทดสอบแรงเฉือนขนาดเล็ก การวิเคราะห์เสถียรภาพของคันดินด้วยวิธีระเบียบคำนวณเชิงตัวเลขได้ทำการคัดเลือกคุณสมบัติของดินจากผลการทดสอบแรงเฉือนโดยตรงจากกล่องทดสอบแรงเฉือนขนาดเล็กกับตัวอย่างดินผ่านตะแกรงเบอร์ 4 และกล่องทดสอบแรงเฉือนขนาดใหญ่ผ่านตะแกรงขนาดช่องเปิด ¾ นิ้ว การคัดเลือกคุณสมบัติกำลังรับแรง

เฉือนของดินที่ใช้ในการวิเคราะห์ได้ทำการคัดเลือกค่ากำลังรับแรงเฉือนของดินที่ใกล้กับจุดปริมาณความชื้นเหมาะสม ผลการวิเคราะห์เสถียรภาพของคันดินพบว่ากำลังรับแรงเฉือนของดินที่ได้จากการทดสอบจากกล่องทดสอบแรงเฉือนขนาดใหญ่มีเสถียรภาพของคันดินสูงกว่ากล่องทดสอบแรงเฉือนขนาดเล็กในลักษณะรูปร่างคันดินเหมือนกันภายใต้ข้อกำหนดสัดส่วนความปลอดภัยไม่น้อยกว่า 2.0 ความลาดชันของคันดินสูงสุดเท่ากับ 29.90 องศาจากคุณสมบัติของดินจากกล่องทดสอบแรงเฉือนขนาดใหญ่และ 13.80 องศาจากคุณสมบัติของดินจากกล่องทดสอบแรงเฉือนขนาดเล็ก

สาขาวิชา วิศวกรรมโยธา ลายมือชื่อนักศึกษา ____________________

ปีการศึกษา 2556 ลายมือชื่ออาจารย์ที่ปรึกษา ________________

THONGCHAI BOONKLUNG : LARGE SCALE DIRECT SHEAR TESTING OF COMPACTED WASTE ROCKS FROM MAE TAN LIGNITE MINE. THESIS ADVISOR : PROF. SUKSUN HORPIBULSUK, Ph.D., 164 PP.

DIRECT SHEAR TEST/SCALE EFFECT/SIZE EFFECT/MINE WASTE/MINE TAILING

A Series of large-scale direct shear test have been performed on waste rocks obtained from the siltstones and claystones overlying the coal seam at Mea Tan lignite mine in Lampang province. The primary objective is to determine the shear strength parameters of the materials that comprise the particles larger than 4.75 mm and cannot be tested by the conventional apparatus. The procedure follows the ASTM standard method. These strength parameters are needed in the stability analysis and design of the in-pit waste piles constructed for the mine rehabilitation and vegetation. The backfill slope is over 200 meters high, which requires compaction to obtain a long-term stability during and after mine decommissioning. The research efforts include (1) field collection of the waste rock samples, (2) development of a new laboratory direct shear box with a diameter of 7.5 inches to accommodate the particle sizes passing sieve opening ¾ in, (3) performing a series of large-scale and small-scale direct shear test on the compacted samples under water contents varying from 2% to 15% and normal stresses from 351.50 kPa to 1406.02 kPa, (4) development of a shear strength criterion for the materials under various water contents, and (5) performing numerical analyses using finite difference FLAC 2D to determine the stability of the compacted waste slopes. The direct shear test results show that the particle size, water content, direct shear box size and relative density affect the shear strength parameters of compacted soils. The friction angle decreases with increasing water content. The soil sample containing larger grain sizes yields higher friction angle. For the large-scale direct shear box, the soil sample containing the particles larger than 4.75 mm has higher friction angle than that containing particles smaller than 4.75 mm. The highest cohesions are found at the optimum water content for the large-scale direct shear box test. Slope stability analysis was undertaken based on the shear strength parameters at optimum water content obtained from both small-scale direct shear box for soil samples passing sieve no.4 and large-scale direct shear box for soil samples passing sieve opening ¾ in. The shear strength parameters obtained large-scale direct shear test give higher factor of safety. To obtain the factor of safety not less than 2.0, the maximum slopes are approximately 29.90 and 13.80 degrees for shear strength parameters obtained from large-scale and small-scale direct shear tests, respectively.

School of Civil Engineering___ Student’s Signature____________________

Academic Year 2013 Advisor’s Signature____________________

ACKNOWLEDGEMENTS

The author wishes to acknowledge the support from the Suranaree University of Technology (SUT) who has provided funding for this research.

Grateful thanks and appreciation are given to Prof. Dr. Kittitep Fuenkajorn and Dr. Decho Phueakphum, member who lets the author work independently, but gave a critical review of this research. Many thanks are also extended to Prof. Dr. Suksun Horpibulsuk, thesis advisor and Dr. Prachya Tepnarong, Chairperson who served to comment on the manuscript.

Finally, I most gratefully acknowledge my parents and friends for all their supported throughout the period of this research.

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SYMBOLS AND ABBREVIATIONS

B_H	=	Berm height
c	=	Cohesion
C_c	=	Coefficient of curvature
CL	=	Low plasticity clay
C_u	=	Uniformity coefficient
D_{10}	=	Diameter of particle of percent finer at 10%
D_{30}	=	Diameter of particle of percent finer at 30%
D_{50}	=	Mean particle diameter (diameter of percent finer 50%)
D_{60}	=	Diameter of particle of percent finer at 60%
e	=	Void ratio
E_{mod}	=	Modified effort energy
FS	=	Factor of safety
G_s	=	Specific gravity of soil
H	=	High of drop of hammer
H/L	=	Aspect ratio
LL	=	Liquid limit
LSDS	=	Large-scale direct shear
n	=	Porosity
N_B	=	Number of blow per layer
N_L	=	Number of layer
owc	=	Optimum water content

SYMBOLS AND ABBREVIATIONS (Continued)

PI	=	Plasticity index
PL	=	Plastic limit
R_w	=	Ramp width
S	=	Degree of saturation
S_H	=	Slope high
SSDS	=	Small-scale direct shear
S_u	=	Undrained shear strength
S_W	=	Slope width
TC	=	Triaxial compression
u	=	Pore water pressure
USCS	=	Unified Soil Classification System
V	=	Volume of mass
V_m	=	Volume of mold
V_S	=	Volume of soil
V_V	=	Volume of void
V_W	=	Volume of water
w	=	Water content
W	=	Weight of hammer
w_d	=	Weight of dry soil
W_s	=	Weight of soil
W_w	=	Weight of water

SYMBOLS AND ABBREVIATIONS (Continued)

ϕ	=	Friction angle
ϕ'	=	Effective friction angle
ν	=	Poison's ratio
ψ_B	=	Berm angle
ψ_f	=	Slope angle
γ, γ_t	=	Unit weight or total unit weight
γ_d	=	Dry unit weight
γ_{d-max}	=	Maximum dry unit weight
γ_s	=	Unit weight of soil
γ_w	=	Unit weight of water
σ	=	Total stress
σ'	=	Effective stress
σ'_n	=	Effective normal stress
σ'_P	=	Maximum past pressure
τ_f	=	Shear strength of soil

CHAPTER I

INTRODUCTION

1.1 Background of problems and significance of the study

Mechanical properties of soil are necessary for the design and analysis of earth structures, soil slope, retaining wall, soil foundation. Soil strength indicates the ability of the soil to carry load. Direct shear testing is one of the oldest strength tests and popular is determining shear strength of soil. The method has been standardized by the American Society for Testing of Materials (ASTM). The standard method has however limited the maximum particle size to one-tenth of the mould diameter or one-sixth of the mould thickness. Direct shear test device is commonly used on diameter of about 60 mm and thickness of about 20 mm (ASTM 3080-98). Some soil samples may have grain sizes larger than that required on the ASTM standard testing. The soil samples are normal sieved to exclude the large particles. For soil mass with larger particle sizes, the obtained result therefore may not truly represent the actual in-situ properties. This research are performed the large-scale direct shear test on soil sample with large size from Mae Tan lignite mine, Lampang province. The sample has maximum particle sizes larger than that required by the ASTM.

1.2 Research objectives

The objective of this research are to performed the direct shear test on the soil sample (or waste rock) with the oversize soil particle (retaining sieve no. 4 but passing sieve opening 3/4 in) from Mae Tan lignite mine, Lampang province using the large scale direct shear box (190.5 mm diameter). The standard scale direct shear (60 mm diameter) as suggested by ASTM standard are also conducted on the soil sample. The results obtained from these two tests use to determine the shear strength parameters base on Coulomb criteria (cohesion and friction angle) for analysis and design the rock pile by using the numerical simulation. The basic properties of soil (grain size distribution, plastic and liquid limit) are tested using for classification rock soil type. The compaction test on large mould and standard mould are performed to determine the maximum dry density and optimum water content.

1.3 Research methodology

As shown in Figure 1.1, the research methodology comprises 8 steps; literature review, sample collection and preparation, basic properties and engineering properties test, direct shear tests, determination of cohesion (c) and friction angle (ϕ), determination basic properties and engineering properties, design of in-pit waste piles, and discussions and conclusions.

1.3.1 Literature review

Literature review is carried out on the subjects result to the determinations of soil strength parameters and the relevant theory of direct shear test. The results of large-scale direct shear test are reviewed from reports, journals, and conference papers. A summary of the literature review is given in the thesis.

1.3.2 Sample collection and preparation

The soil samples (waste rocks) will be collected from Mae Tan lignite mine. The soil collection is disturbed samples contained in the air-tight bag. The soil will be sieved depending on the test indicated of the ASTM standards. The soil preparation and testing will be carried out at the Suranaree University of Technology.

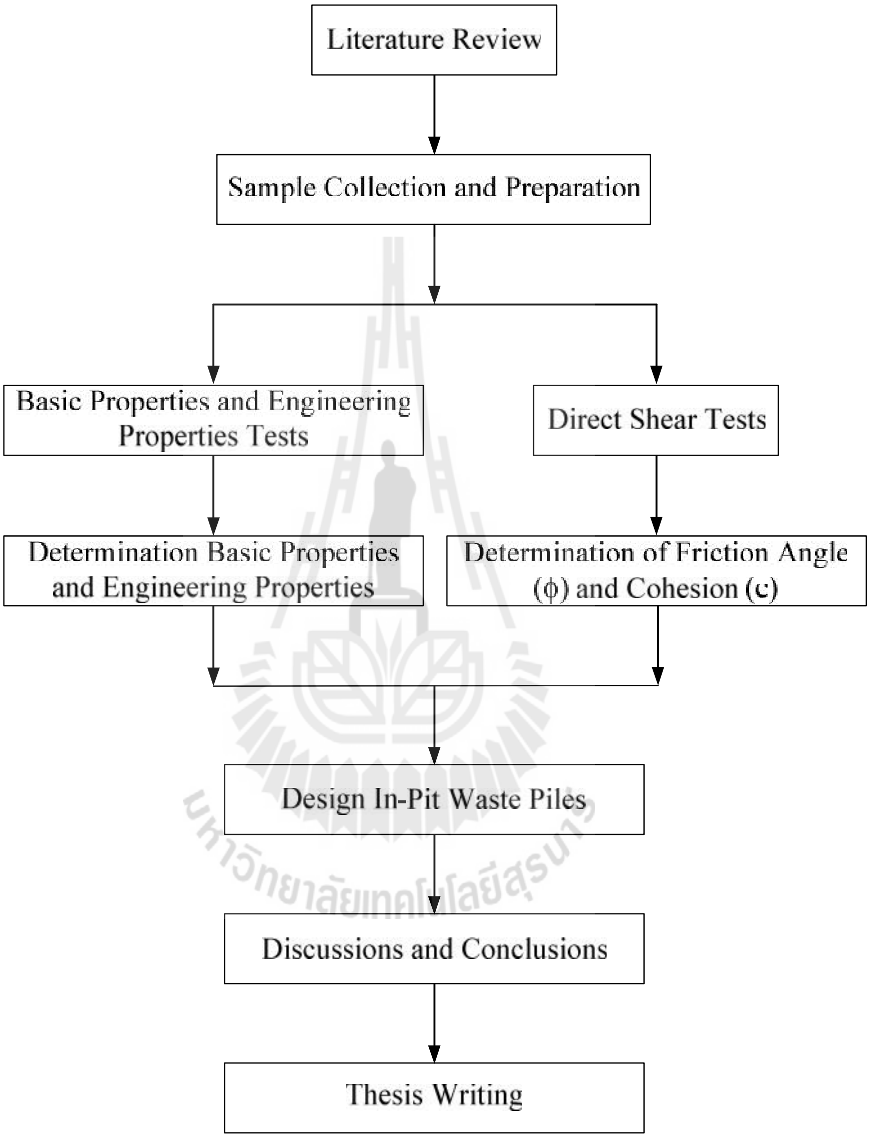

Figure 1.1 Research methodologies.

1.3.3 Basic properties and engineering properties test

Basic properties and engineering properties of soil will be determined for use as a data basis. Testing for the basic properties and engineering properties included Atterberge's limits test (ASTM D4318-05), specific gravity test (ASTM D854-00), grained size analysis (mechanical sieve and hydrometer analysis, ASTM D422-07), compaction test (ASTM D1557-09), and consolidation test (ASTM D2435-04).

1.3.4 Direct shear test

Direct shear test is performed to determine the parameters of soil strength. The test are performed by using of the direct shear boxes with two different sizes, the small-scale direct shear box with 60 mm diameter and 30 mm thickness, and the large-scale direct shear box with 190.5 mm diameter 152.4 mm thickness according to the ASTM D3080-04. All direct shear tests will use three series of soil gradation. The small-scale direct shear testing are performed on soil sample passing sieve no.4 and large-scale direct shear testing on soil sample passing sieve no.4, and sieve opening 3/4 in. Large-scale and small scale direct shear tests start at low water content to the maximum water content that can be compacted on modified proctor energy.

1.3.5 Basic properties and engineering properties determination

Basic properties and engineering properties of the soil tested following the ASTM standard. Atterberge's limit follows Casagrande's method evaluating plastic limit (PL) liquid limit (LL) and plasticity index (PI). Grained size analysis is conducted to determine the relationship between percent finer and grain size by deforming wet sieve and hydrometer analysis. Compaction test is performed to evaluate the relationship between water content and dry density. The results can be obtaining the optimum water content (owc) and the maximum dry density ($\gamma_{d,\ max}$). Consolidation test is performed to evaluate maximum past pressure (σ'_p) this is a guide for direct shear test of using normal stress.

1.3.6 Determination of cohesion (c) and friction angle (¤F

Direct shear test at various water contents can determine cohesion (c) and friction angle (ϕ) by Mohr-Coulomb failure criterion.

1.3.7 Design In-pit waste piles

Design in-pit waste piles will use the basic properties, engineering properties and shear strength parameters of soil from laboratory test. The shear strength parameters will use from large-scale direct shear test of soil sample passing sieve opening.3/4 in and small-scale direct shear test of soil sample passing sieve no.4.

1.3.8 Conclusions and thesis writing

All research activities, methods, and results will be documented and complied in the thesis. This research is application to design mine backfill which soil strength parameter of large scale direct shear test. The research or findings will be published in the conference proceedings or journals.

1.4 Scope and limitations of the study

The scope and limitations of the research include as follows.

1. Fabricate a large-scale direct shear box with a diameter of 190.5 mm and 152.4 mm thick.

2. Laboratory testing will be conducted on waste rocks specimens collecting from Mae Tan lignite mine, Lampang province, Thailand.
3. The collected soil samples are disturbed.
4. Determining the basic properties and engineering properties of soil, including specific gravity, Atterberge's limits, grained size analysis (wet sieve and hydrometer analysis), consolidation test and compaction test.
5. Direct shear testing using small-scale direct shear box (60 mm diameters) and large-scale direct shear box (190.5 mm diameters).
6. Normal stresses used in the direct shear are 351.50 kPa, 703.01 kPa, 1054.51 kPa, and 1406.02 kPa with a constant shear displacement rate of 0.1 mm/minute.
7. Selection the soil parameters of large scale direct shear test and small-scale direct shear test.
8. Design in-pit waste piles using the tested parameters obtained from the laboratory.
9. Performing numerical analyses using FLAC/SLOPE to assess the stability of the designed slopes.

1.5 Thesis contents

Chapter I introduces the thesis by briefly describing the background of problems and significance of the study. The research objectives, methodology, scope and limitations are identified. Chapter II summarizes results of the literature review. Chapter III describes the sample preparation and laboratory experiment. Chapter IV presents the results obtained from the laboratory testing. Chapter V Design and analysis of in-pit waste pile. Chapter VI concludes the research results, and provides recommendations for future research studies. Appendix A provides detailed results of laboratory testing. Appendix B provides detailed results of numerical analysis.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter are summarizes the results of literature review carried out to improve an understanding of the concept development and testing for large-scale direct shear test. The literature review here includes the results of large-scale direct shear and small-scale direct shear test of disturbed sample (under the compactive effort) and undisturbed sample. The shear box sizes are recommended by the ASTM standard which comparison versus of maximum grained size with diameter and depth of shear box. Moreover, soil mechanics theory have reviewed for improve the laboratory test.

2.2 Laboratory tests

Direct shear test has long been used to estimate the shear strength parameters for the analysis of slope stability, retaining wall, and bearing capacity problems. However, the procedure is due to limitation of the testing devices. Most of direct shear test have been performed on soil sample by removing the oversize particles from the soil. Which is the shear strength of testing have been truly.

Bareither et al. (2008) conducted the direct shear test on 30 sand backfill materials having gravel content ranging from 0% to 30% for backfill MSE wall. Testing was conducted on 30 naturally occurring sands having different geologic origins. The maximum dry unit weight (γ_{d-max}) was determined for the materials passing sieve no.4 using the Standard Proctor Test method. Compaction testing was conducted because γ_{d-max} is commonly used in practice for controlling the compaction method of granular backfill. Direct shear box testing are a 64 mm square small-scale direct shear (SSDS) box and a 305 mm square large-scale direct shear (LSDS) box. Triaxial compression (TC) tests were also conducted on four of the backfill materials for comparison with the SSDS and LSDS tests. Direct shear testing was conducted following the procedure in AASHTO T236-92 (AASHTO 2001). The materials were used to ensure that the ratio of box length to maximum particle diameter was at least 10 and that the ratio of box thickness to maximum particle diameter was at least 6. Specimens tested in the SSDS and TC included only material passing sieve no. 4 and LSDS materials retained on the sieve no.4, to a maximum particle diameter of 25.4 mm. Tests were conducted for normal stresses between 26 kPa and 184 kPa of the both shear box. All tests were conducted at a constant rate of 0.24 mm/minute. Maximum horizontal displacements were conducted of 7 mm for small-scale direct shear (SSDS) and 38 mm for large-scale direct shear (LSDS). Friction angles corresponding to peak strength measured in small-scale direct shear (SSDS) and large-scale direct shear (LSDS) differed by no more than 4 degree for a given sand backfill, and in most cases was within 2 degree. The friction angles also were unaffected by removal of the retained on the sieve no.4. Repeatability tests showed that statistically similar failure envelopes are obtained in small-scale direct shear (SSDS) and large-scale direct shear (LSDS), and that highly repeatable friction angles are obtained in small-scale direct shear (SSDS) and the large-scale direct shear (LSDS) methods. No statistically significant difference was found among the failure envelopes measured in small-scale direct shear (SSDS), large-scale direct shear (LSDS), and Triaxial compression (TC), suggesting that friction angles for clean sand backfill with less than 30% gravel can be measured with similar accuracy using any of the three methods.

Cerato and Lutenegger (2006) performed the laboratory to study the specimen size and scale effects of direct shear box tests of sands. There are different size shear boxes in use and the effect of the varying specimen size on the resulting friction angle used in foundation design has never before been investigated thoroughly. Direct shear box tests were performed on each soil in general according with ASTM D3080-90. Three different size shear boxes were used. The first square shear box had a width of 60 mm and a depth of 26.4 mm (aspect ratio, H/L = 0.44). The samples were sheared at a constant rate of 0.25 mm/minutes, which is consistent with the standard rate for drained test on sands. Tests were conducted in a water bath with the sample completely submerged in water to assure that the samples had no cohesion. This was identical to the testing protocol of the surfaces footing tests. The thickness of the 60 mm shear box did not meet the ASTM minimum criteria of six times the maximum particle diameter, or 30 mm (maximum particle size was 5 mm), for the Winter Sand or Gravel Pack #3. The second square shear box had a width of 101.6 mm and a total depth of 40.64 mm (H/L = 0.40). In the two smaller boxes, five tests were performed for each density with five increasing normal stresses (38, 68, 95, 122, and 150 kPa) using a dead-weight system. The third square shear box had a width of 304.8 mm and a depth of 177.8 mm (H/L = 0.58). Five shear tests were performed for each density at five varying normal stresses (69, 103, 138, 172, and 207 kPa) for each relative density. Five sands with different properties were tested in three square shear boxes of varying sizes. The soil samples are tested of 5 types, Brown Mortar (SW), Winter Sand (SW), Ottawa (SP), Morie Sand (SP) and Gravel Pack (SP). Two sands were prepared by moist compaction (Brown Mortar, Winter Sand) and two sands were prepared by dry compaction (Ottawa, Morie Sand). The test results are as followed, at the same density of soil are friction angles decrease when shear box size increase. Friction angle are difference less than 4 degree. Moreover, they report the largest ratio of box length to median particle diameter (L/D_{50}). Test results were conducted with $L/D_{50} \geq$ have sufficient particles in the test specimen to allow local rupture and discontinuities to form, thereby limiting the influence of the shear box boundaries on the shear strength deformation behavior.

Dadkhah et al. (2010) studied the scale effect of direct shear test on the strength parameters of clayey sand in Isfahan city, Iran. The soil samples are classified as SC according to the unified soil classification system. The samples were well graded with dry density ranges between 1.67 and 1.82 g/cm^3. Tested were on the shear strength properties of clayey sand (SC) soil were carried out by using large, medium and small-scale direct shear equipment with shear box diameter of 60, 100 and 300 mm. The undistributed samples, having almost the same properties, were tested in three square shear boxes of varying sizes. Forty five sets of direct shear test at a constant rate 1 mm/minutes were performed to study the influence size of the shear boxes and soil density on the strength parameters. The results show that the friction angle and cohesion were most affected by shear box size. The direct shear test shows that the friction angle and cohesion can be dependent on shear box size. The medium and large-scale direct box test having almost the same results, show a higher cohesion and lower friction angle compared with the result of the small-scale direct shear test result. The friction angle and cohesion show an increase with increasing density in each of three shear boxes.

Hight and Leroueil (2003) presented data from tests performed on dense sand in different size shear boxes. Instead of varying the width of shear box, they used a 254 mm square box and varied the high of specimen between 50.8 and 154.9 mm. They presented their results as the ratio of shear stress to normal stress versus the aspect ratio (H/L), and shown as aspect ratio increased, the ratio of shear stress to normal stress increased. The increase of the height of the shear box influences the stress distribution of the specimen shear plane during the test which increases the normal stress at the top of the box and reduces it at the bottom in a more pronounced way than what would occur in standard direct shear boxes. This nonuniform stress distribution is a consequence of the moment of the shear force applied to the upper half of the box which is transferred to the soil specimen by the internal wall of the upper half of the box. This may be one reason for the influences of the box aspect ratio on friction angles. This research are show that it is important to take the aspect ratio into account when performing direct shear boxes and understand that varying this parameter may result in different values of friction angle. This is important to keep the height of the box large enough in relationship to mean grain size for a shear zone to form, it is also important to shear sands in boxes with adequate length, for full propagation of the shear zone.

Nakao and Fityus (2009) performed the direct shear testing using large shear box to determine effective strength parameter of the coarse grain soil of backfills for reinforced earth walls. This test were conducted on the same soil at two or three different shearing rates and using direct shear boxes of two different sizes. Shear box tests used two boxes size, 300 mm square and 190 mm depth for a large shear box and 60 mm square and 50 mm depth for a small shear box. Four individual shearing tests were performed under imposed normal stresses ranging from about 100 kPa to 400 kPa. Sample being tested, the largest 19 mm for testing in a large shear box and the largest 4.75 mm for testing in a small shear box. The soil samples of those are GM (silty sandy gravel) of the largest 19 mm and SM (silty gravel sand) of the largest 4.75 mm which is classification by USCS. Shearing rates effect, tests were carried out at 7.06, 0.63 and 0.05 mm/minutes for a large shear box and 6.03 and 0.42 mm/minutes for a small shear box, the large shear box at fast speed test showed that the internal friction angle is higher than slow speed test as opposed to the small shear box. Scale effect, tests were carried out in a similar rate 0.63 mm/min for the large shear box and 0.42 mm/min for the small shear box. The results showed that a large shear box test for the internal friction angle obtained from a large shear box test is higher than those obtained from the small shear box test. Size effects were carried out a large shear box test using two grain size for the test. Sample being tested, the largest 19 mm for testing in large-scale shear box and the largest 4.75 mm for testing in small-scale shear box. The soil samples of those are silty gravel (GM) and silty sand (SM). Shearing rates effect, tests were carried out at 7.06, 0.63 and 0.05 mm/minutes for a large shear box and 6.03 and 0.42 mm/minutes for a small shear box. At the both fast and slow shearing speed, the results for small shear box tests show a peak shear stress value being reached by around 10% strain, the results for large shear box tests show a peak shear stress at strain of 7% to 10% and at nearby shearing speed of both tests shear stress of large shear box are higher than small shear box, which are comparing at the same shear strain. In almost all case, the large shear box results indicate higher shear strength values than small shear box. Scale effects, in almost all case, friction angle of large shear box are higher than small shear box. The different of friction angle results are not more than 2 degrees for the granular soil.

Wongtape et al. (2007) studied the efficiency of the large scale direct shear test apparatus. It is designed to testing a large scale direct shear, which is 0.6 meters wide, 1 meter long, 0.3 meter thick. The soil samples were tested using three types, gravel, clay and sand. Sample preparation prior to the test sample will be compacted at optimum water content and dry density checking by sand cone method and tested for comparison with conventional methods. Tests were conducted for normal stresses including 27.30 kPa, 54.50 kPa, and 184 kPa of the all shear box. The test results showed that, the internal friction angle and cohesion of small shear box is higher than large shear box of clay, the internal friction angle of small shear box is lower than large shear box and cohesion of small shear box is higher than large shear box of sand and the internal friction angle of small shear box are lower than large shear box and cohesion is zero of both shear box of gravel.

Wu et al. (2008) conducted direct shear test to study the effects of specimen size and some other factors on the strength and deformation of granular soil. Direct shear testing are used four square shear box including small (40 mm x 40mm x 20 mm), semi-medium (120 mm x 120 mm x 120 mm), medium (300 mm x 300 mm x 300 mm) and large (800 mm x 500 mm x 600 mm). Two samples were tested of those shear box as of fine poorly graded sand (Toyoura Sand) and Sandy Gravel (GM). The effect of specimen size were evaluated by performing constant shear displacement rate on a fine poorly graded sand in the small, semi-medium, medium, and large direct shear box test and a well graded sandy gravel in a medium direct shear boxes test. The scale effect was evaluated by using medium direct box test of two materials. All of tests performed under low displacement rate about 0.30 mm/minutes. Test results are as follows, the effect of specimen size has been the peak strength decrease with an increase specimen size, and the size effect has been the peak strength increase with an increase sample size. Moreover, the peak strength decreases with an increase void ratio. They concluded the mechanical boundary effect is mitigated as the shear box increases, the ratio of L/D_{50} increase. Therefore, they have reported the boundary of shear zone is about 18 times of mean grained size distributions.

Yazdanjou et al. (2008) studied the effect of gravel content on the shear behavior of sandy soils. This research has been planned to investigate the shear strength of sandy soils containing difference gravel contents. The tests were used a large scale direct shear box with 300 mm x 300 mm. All the tests have been performed on dry sample in drained condition. The gravel content of 20, 40 and 60 percent were used in sample preparation. The test conducted in three difference densities of 35, 60 and 85 percent and three difference normal stresses of 150, 300 and 450 kPa. The shear strength has been increase with gravel content and relative density increase.

2.3 Soil mechanics

2.3.1 Phase relationships

Phase relationships are also known as weight-volume relationships. Phase relationships are the basic soil relationships used in geotechnical engineering. In essence, the phase relationships provide the mechanical description of the soil and they are used in engineering analyses. The phase relationships are including solids, liquids and gas. Those phase diagram relationships is shown in Figure 2.1. Solids are the mineral soil particles. Liquids are usually water that is contained in the void spaces between the solid mineral particles. Gas is also contained in the void space between the solid mineral particles. If the soil below ground water table is usually saturated and there are no open gas void.

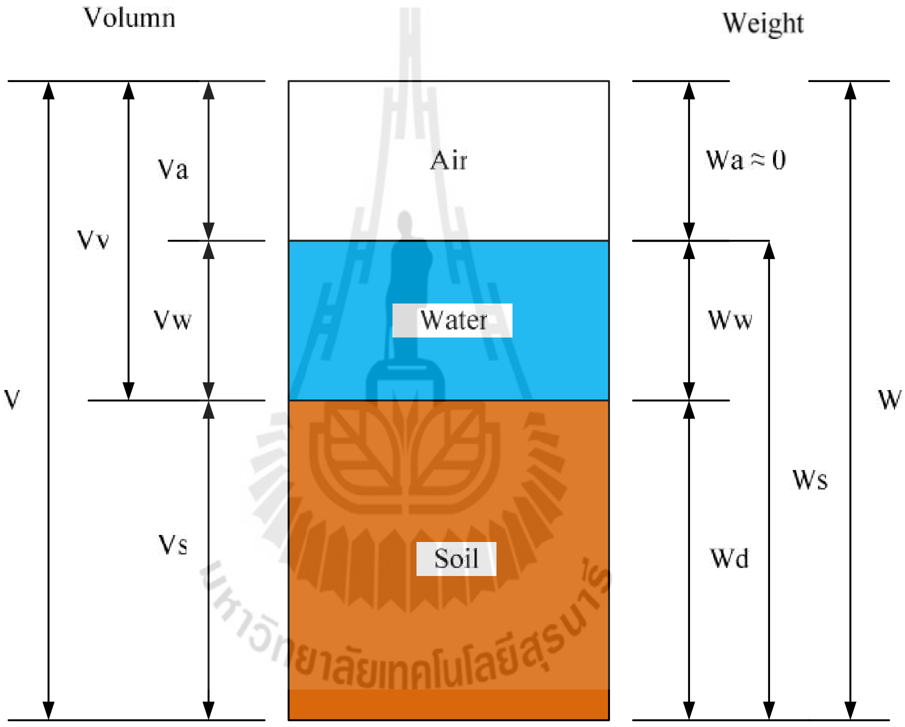

Figure 2.1 Soil phase diagram.

For many soils, the water content may be extremely important index used for establishing the relationship between the soils behaves and its properties. The consistency of soil behavior depends on its water content. The water content is also used in expressing the phase relationship of air, water and solids in a given volume of soil.

Unit weight or total unit weight (γ_t) is the weight of soil (W or W_s) per unit volume (V). The general expression is defined as

$$\gamma_t = W_s/V \tag{2.1}$$

The unit weight can vary from a minimum at a dry state to a maximum at the saturated state for a given particle arrangement.

Void ratio (e) is the volume of void (V_v) per volume of soil (V_s). The calculation is defined as

$$e = V_v/V_s \tag{2.2}$$

Porosity (n) is the volume of void (V_v) per volume of mass (V). The calculation is defined as

$$n = V_v/V \tag{2.3}$$

The void ratio and porosity indicate the relative amount of void space in soil. The typical till consists of a well-graded soil ranging in particle sizes from clay to gravel and boulders. The high density and low void ratio are due to the extremely high stress exerted.

Degree of saturation (S) is the ratio of volume of water to the volume of the soil void. The degree of saturation indicates the degree to which the soil voids are filled with water. A totally dry soil will have a degree of saturation of 0 percent, while a saturated soil will have a degree of saturation of 100 percent. If a soil is obtained below the ground water table or after submergence in the laboratory the degree of saturation is commonly assumed to be 100 percent and then phase relationship are back calculated. However, for soil below ground water table, a better approach is to use the degree of saturation as a final check on the accuracy on the laboratory test. The generally expressed is defined in the percentage as

$$S = V_w/V_v \text{ x}100 \quad (2.4)$$

Specific gravity of soil (G_s) is the unit weight of soil per the unit weight of water. The calculation is defined as

$$G_s = ((W_s/V_s)/\gamma_w) = (\gamma_s/\gamma_w) \quad (2.5)$$

Water content (w) or also know as moisture content is probably the most common and simple type of laboratory test. The calculation is defined as

$$w = (W_w/W_d) \text{ x } 100 \quad (2.6)$$

2.3.2 Soil classifications

Soil classification is the method used to purpose the soil type and predict the soil behavior introductory. In the soil classification method is mostly used the Unified Soil Classification System (USCS). The basic element of the USCS is the determination of the amount and distribution of particle size larger than 0.0075 mm (retained sieve no.200) is determined by sieving and the distribution of particle size smaller than 0.0075 mm by the hydrometer analysis. For the USCS, the rocks fragments and soil particles versus size are defined as Boulders is rock that have an average diameter greater than 300 mm, Cobbles is rock that is smaller than 300 mm and retained on 75 mm sieve (USCS standard sieve), Gravel is rock or soil that is smaller than 75 mm sieve and retained 4.75 mm sieve, Sand is soil that is smaller than 4.75 mm sieve and retained 0.075 mm sieve, Silt is the fine soil that is passing 0.075 mm sieve and larger than 0.002 mm, Clay is the fine soil that is passing 0.075 mm sieve and smaller than 0.002 mm, It is important to separate between the size of soil particle and the classification of the soil.

To determine whether a material is uniformly graded or well graded as proposed the following as

$$C_u = D_{60}/D_{10} \tag{2.7}$$

The uniformity coefficient (C_u) is about one if the grain size distribution curve is almost vertical, and the value increases with gradation. For all purposes we can consider the following values for granular soils as

$C_u > 4$ for well graded gravel

$C_u > 6$ for well graded sand

$C_u < 4$ for uniformly graded soil containing particles of the same size

There is another step in the procedure to determine the gradation of particles. This is based on the term called the coefficient of curvature which is expressed as

$$C_c = D^2_{30}/(D_{10} x D_{60}) \tag{2.8}$$

The soil is said to be well graded if C_c between 1 and 3 for gravels and sand. Where, D_{60}, D_{30} and D_{10} are the diameter of the particle of percent finer on the grain size distribution curve.

These two parameters are used in the USCS to determine weather a soil is well graded or poorly graded. The USCS has specific size dimensions for boulders, cobbles, gravel and sand. There are many other classification systems that use different particle size dimensions and terminology. USCS separates soils into two main group, coarse-grained soils and fine-grained soils. The basis of the USCS is that the engineering behavior of coarse-grained soils is based on their grain size distributions and the engineering behavior of fine-grained soil is related to their plasticity characteristics. The USCS summary is shown in Table 2.1.

Soil classification of fined grain soil is using plasticity chart is shown in Figure 2.2. The Atterberg's limits can be used to separate between silt and clay, and it can separate between different types of those.

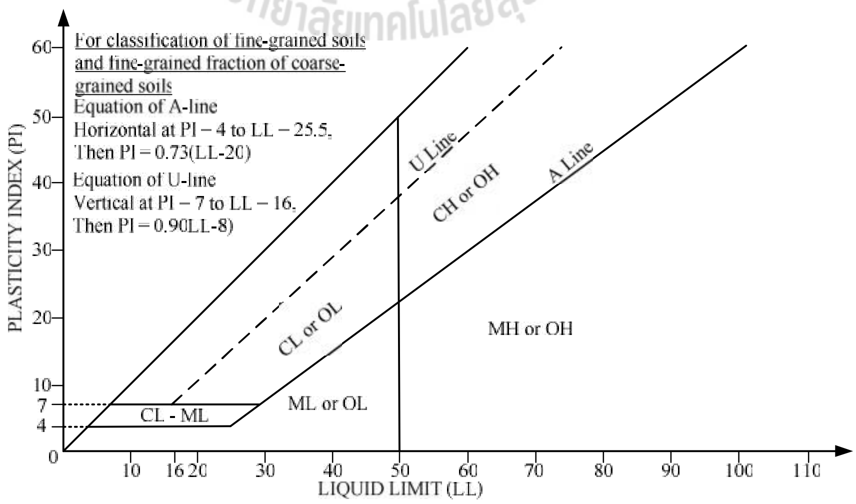

Figure 2.2 Plasticity chart

Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid is showing in Figure 2.3. In each state the consistency and behavior of a soil is different and that are its engineering properties. The boundary between each state can be defined based on a change in the soils behavior.

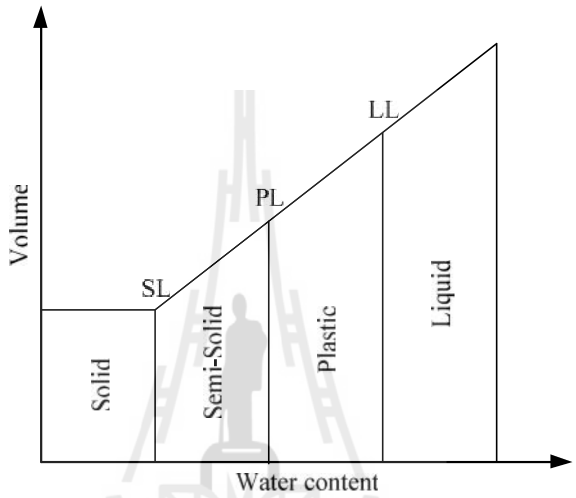

Figure 2.3 Soil state consistencies by water

Table 2.1 Unified Soil Classification Systems

Major divisions	Subdivisions	USCS symbol	Typical names	Laboratory classification criteria	
Coarse-grained soils (More than 50 percent retained on no.200 sieve)	Gravels (More than 50 percent of coarse fraction retained on no.4 sieve)	GW	Well-graded gravel-sand mixtures, little or no fines	Less than 5 percent fines*	Cu ≥ 4 and 1≤ Cc ≤ 3
		GP	Poorly graded gravels or gravelly sands, little or no fines	Less than 5 percent fines*	Does not meet Cu and/or Cc criteria listed above
		GM	Silty gravels, gravel –sand-silt mixtures	More than 12 percent fines*	Minus no.40 soil plots below the A line
		GC	Clayey gravels, gravel-sand-clay mixtures.	More than 12 percent fines*	Minus no.40 soil plots on or above the A line
	Sands (50 percent of more of coarse fraction passes no.4 sieve)	SW	Well-graded sands or gravelly sands, little or no fines	Less than 5 percent fines*	Cu ≥ 6 and 1≤ Cc ≤ 3
		SP	Poorly graded sands or gravelly sands, little or no fines	Less than 5 percent fines*	Does not meet Cu and/or Cc criteria listed above
		SM	Silty sands, sand-silt mixtures	More than 12 percent fines*	Minus no.40 soil plots below the A line

Table 2.1 Unified Soil Classification Systems (Continued)

		SC	Clayey sands, sand-clay mixtures	More than 12 percent fines*	Minus no.40 soil plots on or above the A line
Fine-grained soil (50 percent or more passes no.200 sieve)	Silt and clays (liquid limit less than 50)	ML	Inorganic silt, rock flour, silts of low plasticity	Inorganic soil	PI < 4 or plots below A line
		CL	Inorganic clays of low plasticity, gravelly clays, sandy clays, etc.	Inorganic soil	PI > 7 and plots on or above A line
		OL	Organic silts and organic clays of low plasticity	Organic	LL (Oven-dried)/LL (not dried) < 0.75
	Silt and clays (liquid limit 50 or more)	MH	Inorganic silts, micaceous silts of high plasticity	Inorganic soil	Plots below A line
		CH	Inorganic highly plastic clays, fat clays, silty clays, etc.	Inorganic soil	Plots on or above A line
		OH	Organic silts and organic clays of high plasticity	Organic	LL (oven-dried)/LL (not dried) < 0.75

2.2.4 Shear strength of soil

An understanding of the shear strength of soil is essential in foundation engineering. This is because most geotechnical failure involves a shear type failure of the soil. This is due to the nature of soil, which is composed of individual soil particles that slide when the soil is loaded. The shear strength of soil is required for many different types of engineering analyses. The shear strength of soil can be divided into two broad categories; (1) cohesionless soil, also known as non-plastic or granular soils and (2) cohesive soils, also known as plastic soil.

To fully understand shear strength testing, the concept of effective stress will first be introduced. The effective stress is defined as

$$\sigma' = \sigma - u \tag{2.9}$$

Where, σ' is effective stress σ is total stress and u is pore water pressure.

In shear strength testing, the total stress acting on the soil specimen can be determined as the load divided by the area over which it acts. The pore water pressure in the soil is typically assumed to be equal to zero in the case of saturated cohesionless soil that is slowly sheared in direct shear apparatus or measured by the pore water pressure transducer in the case of a triaxial test on cohesive soil. The concept of effective stress is also used for field applications. The cohesionless soil can be defined the shear strength of soil as

$$\tau_f = c' + \sigma'_n \tan\phi' \tag{2.10}$$

Where τ_f is shear strength of soil, c' is effective cohesion; σ'_n is effective normal stress and ϕ' is effective friction angle.

The effective cohesion (c') and the effective friction angle (ϕ') are known as "effective shear strength parameters" of soil. In essence, the shear strength parameters indicate how strong the soil will be when subjected to a shear stress. Non-plastic soils or cohesionless soils, when have a clay particle is low contain there is no cohesion acting between the soil particles. The shear strength of soil is defined as

$$\tau_f = \sigma'_n \tan\phi' \quad (2.11)$$

Cohesionless soils are included gravels, sands and non-plastic silt. A cohesionless soil develops its shear strength as a result of the frictional and interlocking resistance between the individual soil particles. Cohesionless soils can only be held together by confining pressures and will fall apart when the confining pressure is released. The effective normal stress is the effective stress that is acting perpendicular to the shear surface. It is the shear that is normal to the shear surface. The effective normal stress can be determined from basic geotechnical engineering principles. The effective friction angle is an intrinsic property of the soil and can be determined from laboratory or field testing.

The cohesive soil is the fine particle, which are silt and clay that give the soil a plasticity or ability to be molded and rolled. The shear strength of cohesive soil is much more complicated than the shear strength of cohesionless soils. Generally the shear strength of cohesive soil tends to be lower than the shear strength of cohesionless soil. The laboratory shear strength testing of cohesive soil can generally be divided into three broad group, undrained shear strength, drained shear strength and drained residual shear strength.

Undrained shear strength (S_u) is the shear strength based on total stress analysis. These types of shear strength test are often referred to undrained shear strength test because there is no change in water content of the soil during the shear portion of the test. Example of testing includes unconfined compression test, vane shear test, unconsolidated undrained triaxial compression test and consolidated undrained triaxial compression test. The shear strength of those test methods is defined as

$$\tau_f = S_u \tag{2.12}$$

Drained shear strength is the shear strength based on an effective stress analysis. The purpose of laboratory tests is to obtain the effective shear strength of the soil based on the failure envelope in terms of effective stress (effective stress cohesion and effective stress friction angle). Example of testing includes consolidated drained triaxial compression test.

Drained residual shear strength is the shear strength obtained the residual shear strength of cohesive soil, which is define as the remaining shear strength after considerable amount of shear deformation has occurred. Drained residual shear strength is used to obtain the residual failure envelope in terms of effective stress. The drained residual shear strength can be obtained by shearing back and forth a specimen in direct shear apparatus or by using the torsional ring shear apparatus

CHAPTER III

LABORATORY TESTS

3.1 Introduction

Laboratory test is defined the properties of soil. The properties of soil is defined the soil characteristics. Test method are according ASTM standard test. The soil sample is backfill materials of mine rehabilitation. One of five soils of all backfill materials are low shear strength. The sample collection to this research is selected of lowest shear strength parameter. Laboratory test are determining the basic properties and engineering properties of soil. The test results will be discussion for analysis and design in-pit waste piles.

3.2 Sample collection

Disturbed soil sample was obtained from Mae Tan lignite mine. The material has a maximum particle size of 20 mm. They were kept in air tight bag s to control their moisture content as in situ condition. The initial water content is necessary for the discussion to the design and construction in-pit waste piles.

3.3 Sample preparation

The preparation of soil sample to be used for laboratory testing is commonly normal sieved that is required of ASTM standard. The laboratory test method to find the basic properties and engineering properties of soil are following ASTM standard.

The samples was mixed have taken before sieved for reduce variability of laboratory test results.

3.4 Laboratory tests

3.4.1 Natural water content

The natural water content test should be the first operated owing on indicated the water content of a field. This test method is following ASTM D2216. This test method is determination the water (moisture) content by mass of soil, rock and similar materials where the reduction in mass by drying is due to loss of water. This test can be performed on disturbed and undisturbed sample. The water content (w) is the ratio, expressed as percentage of a weight of water (W_w) in a given weight of soil (W_s) to the weight of dry soil (W_d). The water content test consists of determining the weight of wet soil (W_s) specimen and then drying the soil in an oven about 12 to 16 hours at a temperature of 110 °C ± 5 °C in order to determine the weight of dry soil (W_d). The loss of mass due to drying is considered to be water.

3.4.2 Atterberge's limit

Atterberge's limit test is one of test method to find the plastic limit (PL), liquid limit (LL) and plasticity index (PI) of fine grained soils. The Atterberge's limits are defined as the water content corresponding to different behavior condition of fined grain soil (silt and clay). This test method is following ASTM D4318. The sample preparation is processed to remove any material retained on sieve no.40. The liquid limit is arbitrarily defined as the water content in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2 in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbing. The plasticity index is calculated by the difference between the liquid limit and the plastic limit.

3.4.3 Specific gravity

The specific gravity test is performed determine the specific gravity of soil (G_s) by using a pycnometer. This test method is following ASTM D854. The test method are cover the determination of the specific gravity of the soil solids that passing sieve no.4. The specific gravity of soil is defined as the density of soil (γ_s) divided by the density of water (γ_w). The specific gravity of soil is the ratio of the weight of unit volume of soil at stated temperature to the weight of the same volume of gas-freed is tilled water at a stated temperature. The determination of specific gravity of soil, about 25 grams of moist or oven dried soil sample is thoroughly pulverized and is placed in a calibrated pycnometer. The water is poured incise the pycnometer until it is top is slightly below the calibrated pycnometer mark. The mixture is boiled thoroughly in order to eliminate all the air bubbles. More water is added to the mixture till it overnight, the temperature is then recorded and the bottle is weighed. The term of soil solids is typically assumed to mean naturally occurring mineral particles or soil like particle that are not readily soluble in water. Therefore, the specific gravity of soil solid containing extraneous matter, such as sodium chloride, and soils containing matter with a specific gravity less than one, typically require special treatment or a qualified definition of their specific gravity. Soil solids for this test method do not include solid which can be altered by this method, contaminated with a substance that prohibits the use for this method, or are highly organic soil solid.

3.4.4 Grain size analysis

The grain size analysis is performed to determine the percentages of different grain sizes contained within a soil. This test method is following ASTM D422. The distributions of particle sizes larger than 0.075 mm (retained sieve no.200) is determine by sieving, while a sedimentation process (hydrometer analysis) is used to determine the distribution of particle sizes smaller than 0.075 mm (passing sieve no.200). The sieve analysis is testing by wet process. The soil sample is on the top of sieve opening ¾ in and then washes the soil sample by water. Sieve properties following ASTM standard is shown in Table 3.1.

Table 3.1 Sieve number and sieve opening

No.	Sieve no.	Sieve opening (mm)
1	-	19.000
2	-	9.500
3	4	4.750
4	10	2.000
5	20	0.850
6	40	0.425
7	60	0.250
8	100	0.150
9	200	0.075
10	Pan	-

The hydrometer analysis is adopted for sample passing sieve no.200. The hydrometer analysis testing, a sample passing sieve no.200 of the oven dry sample, is thoroughly mixed with required quantity of water in a calibrated glass cylinder. In order to avoid flocculation, a little dispersing agent is added. The density of the suspension at the level of hydrometer can be computed by means of Stocks law, whereas the weight of the particles finer than that size can be computed from the density of the suspension at the same level. The results are represented by cumulative curve plotted on semi-logarithm graph.

3.4.5 Compaction test

Compaction test is performed to determine the relationship between the water content and the dry density (γ_d) of a soil for a specified compactive effort. This test method is following ASTM D1557. The compaction test performed under modified effort energy (E_{mod}) of 2,700 kN.m/m^3 (56,000 Ibf.ft/ft^3) by using two different sizes of mold; standard mold with 4 inches diameter with sample passing sieve no.4 and large mold with 7.5 inches diameter with sample passing sieve no.3/4. The compactive effort energy is defined as

$$E_{mod}= ((N_B)(N_L)(W)(H))/V_m \qquad (3.1)$$

Where N_B is number of blows per layer, N_L is number of layers, W is weight of hammer, H is height of drop of hammer, and V_m is volume of mould. The test result is plotted dry density with water content for maximum dry density and optimum water content.

3.4.6 Consolidation test

The compression of soil under the action of static load and with decrease of void ratio due to expulsion of water from the soil pores is called consolidation. This test method is following ASTM D2435. The test method cover procedures for determining the magnitude and rate of consolidation of soil when it is restrained laterally and drained axially while subjected to incrementally applied controlled-stress loading. This test method is performed with constant load increment duration of 24 hours. Time-deformation readings are required on a minimum of two load increments. Consolidation test is most commonly performed on undisturbed samples of fined grained soil naturally sedimented in water, however, the basic test procedure is applicable, to specimen compacted soil and undisturbed sample of soil formed by other processes such as weathering or chemical alteration. For this testing is performing on compacted soil in standard mold within modified effort energy. The sample is prepared that by carefully trimming it to the required dimension with the consolidation box. The normal stresses are defined from depth of mine excavation about 200 meters. Test result is plotted the corresponding normal stress in log-scale with accumulated settlement. The maximum past pressure (σ'_p) is determined by Casagrande method (1936).

3.4.7 Direct shear test

Direct shear test are performed to determine the shear strength parameters of soil. The test procedure follows the relevant ASTM standard (ASTM D3080). This test method covers the determination of the consolidated drained shear strength of a soil material in direct shear test. The test is performed by deforming a specimen at a controlled strain rate on or near a single shear plane determined by the configuration of the apparatus. Generally, three or more specimens are tested, each under a difference normal load, to determine the effect upon shear resistance and displacement, and strength properties such as Moh strength envelopes. Shear stress and displacement are nonuniformly distributed within the specimen. An appropriate height cannot be defined for calculation of shear strains. Therefore, stress-strain relationships or any associated quantity such as modulus cannot be defined from this test. The determination of strength envelopes and the development of criteria to intercept and evaluate test result are requesting the test. The test condition including normal stress and moisture content are selected which represent the field conditions being investigated. The scale of shear boxes must be diameter per thickness of 2:1. This research are using direct shear box of two different sizes; small-scale direct shear box with 60 mm diameter and 30 mm thickness and large-scale direct shear box with 190.5 mm diameter and 152.4 mm thickness. Small-scale direct shear box is used the existing direct shear box in soil laboratory of Suranaree University of Technology. Large-scale direct shear box is modified from direct shear box for rock testing. The test machines of both direct shear boxes are shown in Figure 3.1 and 3.3. The sample prepared for testing is compacted of modified proctor energy and the varying water content. Normal stresses are ranging between 351.50 kPa to 1406.02 kPa of overburden pressure about 200 meters from ground level. The depth of mine excavation about 200 meters is shown in Figure 3.3. The shearing rate is using as low speed about 0.5 mm/minutes, which is the occurrence exceed pore water pressure. The peak strength is calculated and plotted the corresponding normal stresses with shear strength. The test results are summarized the shear strength parameters of plotted friction angle with water content and cohesion with water content. The results of laboratory test are informed to the discussion for the analysis and design in-pit waste piles.


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CHAPTER IV

TEST RESULTS

4.1 Introduction

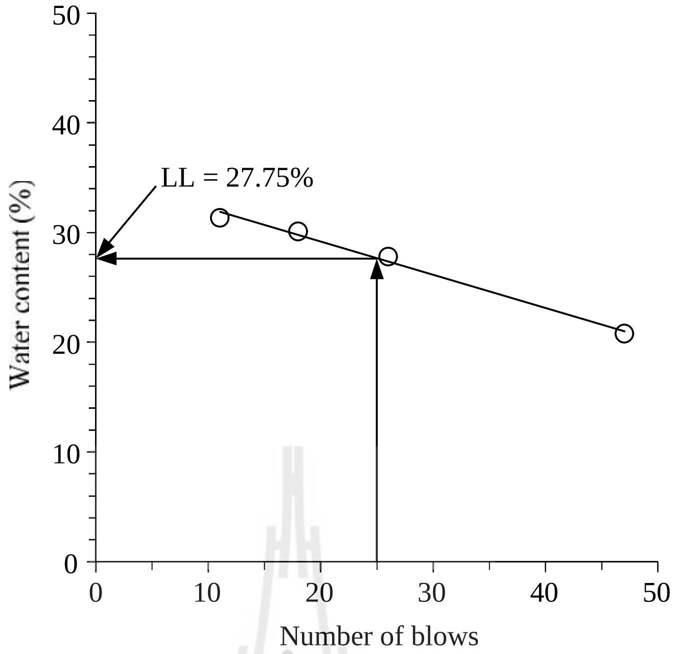
This chapter proposed the results obtained from the laboratory testing. The test results are including natural water content, Atterberge's limit, specific gravity, grained size distribution, compaction test, consolidation test and direct shear test. The behaviors of soil are indicated the soil types.

4.2 Natural water content

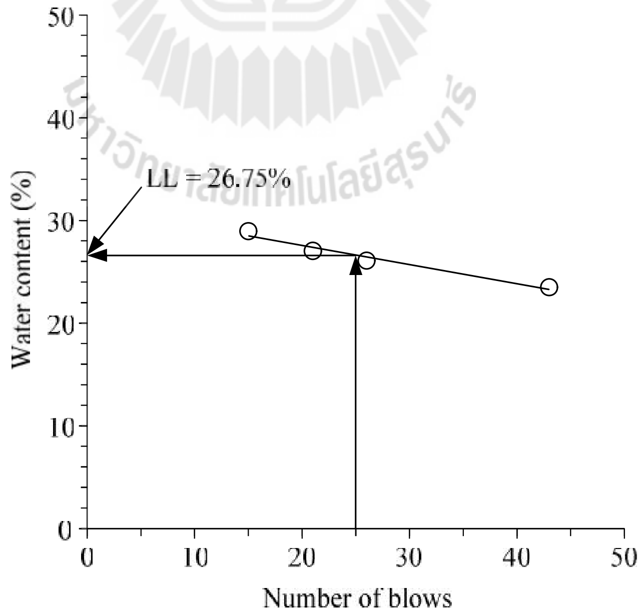
The natural water content is testing of 5 samples. The test results are about 11.46%, 9.60%, 12.33%, 10.74% and 10.99%. The average natural water content is about 11.03%.

4.3 Atterberge's limit

Plastic limit and liquid limit obtained from the test using two soil sample. Plastic limit are 15.38% and 15.81%. The average value of plastic limit is 15.60%. Liquid limit test results are 27.75% and 26.75% as shown in Figure 4.1 and 4.2. The average value of liquid limit is 27.25%. Plasticity index can be calculated as 11.66%.



LL = 27.75%
Water content (%)
Number of blows



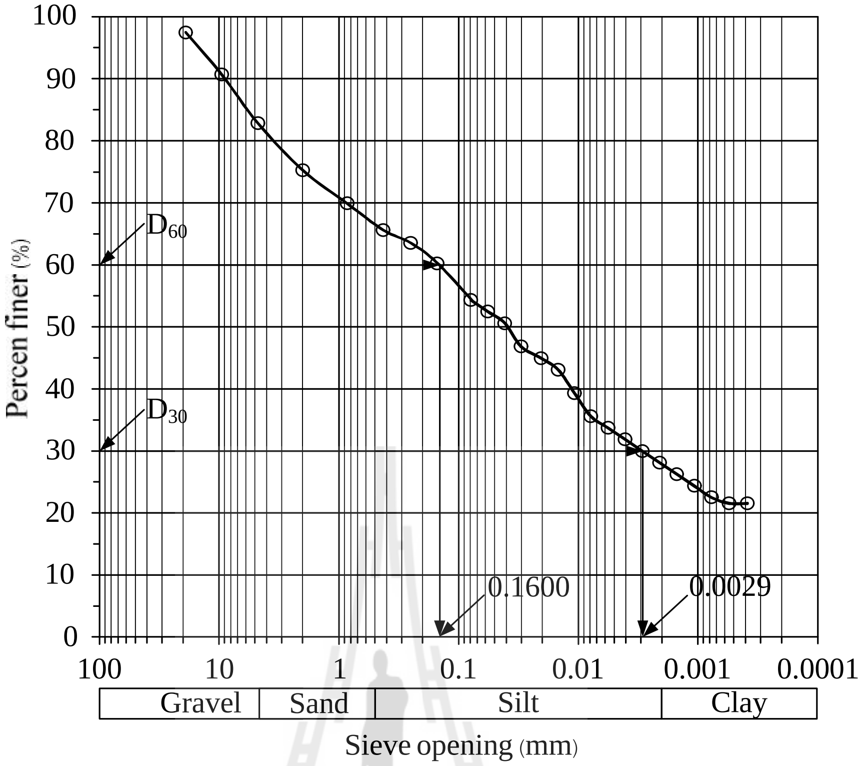
LL = 26.75%
Water content (%)
Number of blows

4.4 Specific gravity

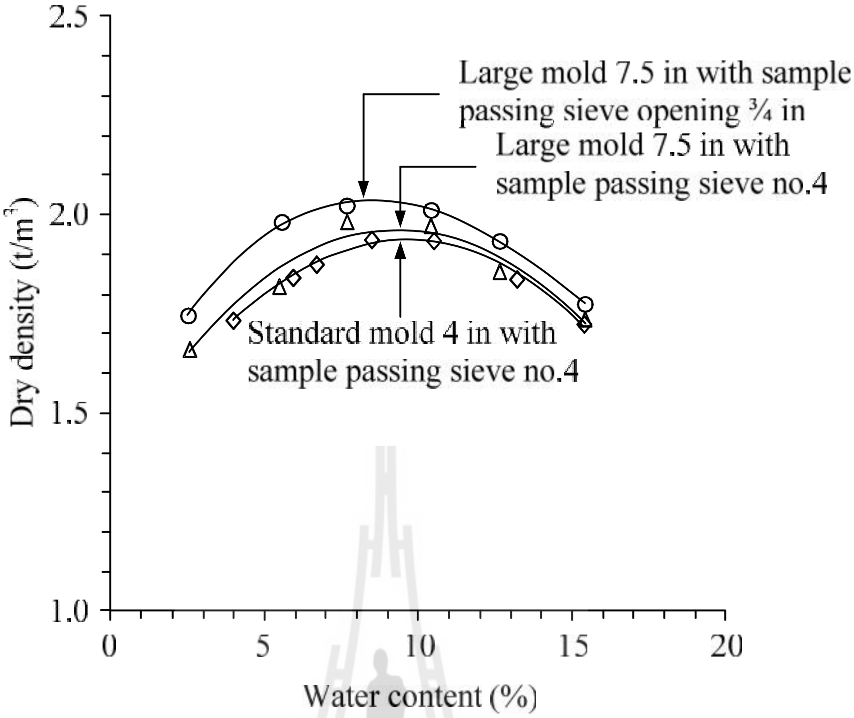
The specific gravity is a dimension parameter that relates the density of the soil particles to the density of water. The determination of the dry mass of the soil is using a pycnometer to obtain the volume of the soil solids (ASTM D854). Specific gravity test have been often only performed on representative soil sample. Specific gravity tests are measured from 3 samples. Specific gravity values are including 2.75, 2.77 and 2.77. The average specific gravity is 2.76.

4.5 Grained size distributions

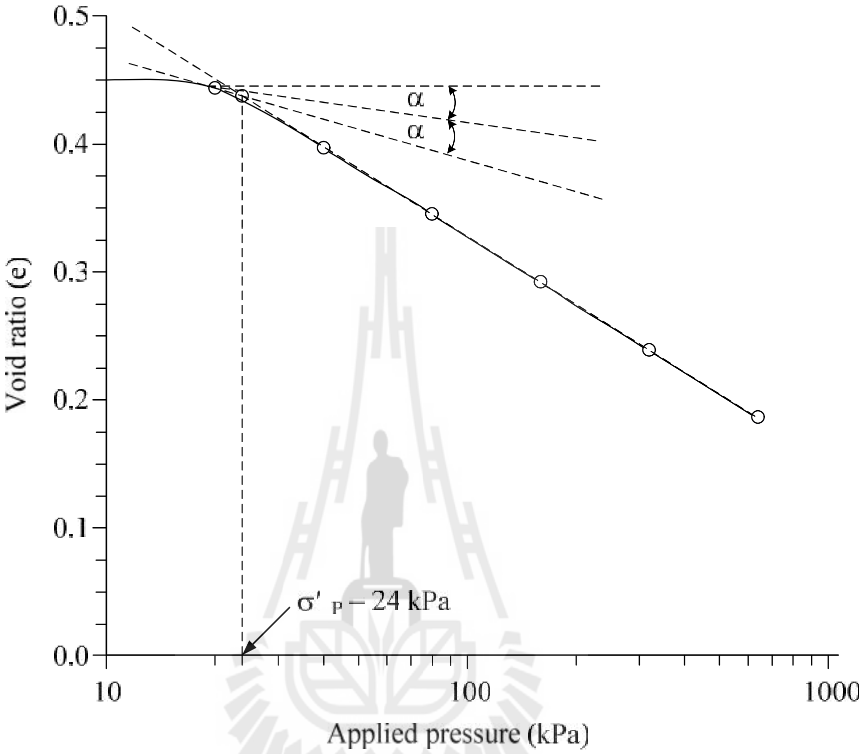
The grained size analysis is the methodology to present the grained size distributions of soil. In the process were tested by wet mechanical sieve and hydrometer analysis. The relationship of percent finer with grained size distributions have plotted on the semi-log graph as showing in Figure 4.3. The soil fabrication has containing gravel 25%, sand 10%, silt 37% and clay 28%. Soil classification is following Unified Soil Classification System (USCS). The USCS has been classified soils into two main group, coarse grained soils and fine grained soils. This soil sample can be classified as low plasticity clay (CL).


100
90
80
70
60
50
40
30
20
10
0
Percen finer (%)
D_{60}
D_{30}
0.1600
0.0029
100
10
1
0.1
0.01
0.001
0.0001
Gravel
Sand
Silt
Clay
Sieve opening (mm)


101.6 mm



No.	Mold Size	Sample type	owc (%)	$\gamma_{d\text{-}max}$ (t/m^3)
1	Standard Mold 4 in.	Passing Sieve no.4	9.50	1.90
2	Large Mold 7.5 in.	Passing Sieve no.4	9.50	2.00
3	Large Mold 7.5 in.	Passing Sieve opening ¾ in	9.00	2.05



0.5
0.4
0.3
0.2
0.1
0.0
Void ratio (e)
α
α
σ' P – 24 kPa
10
100
1000
Applied pressure (kPa)

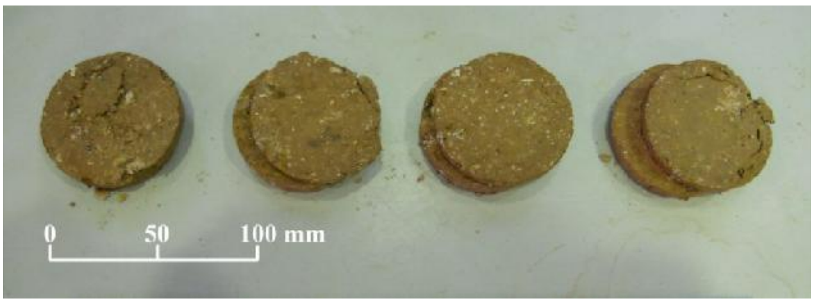
4.8 Direct shear test

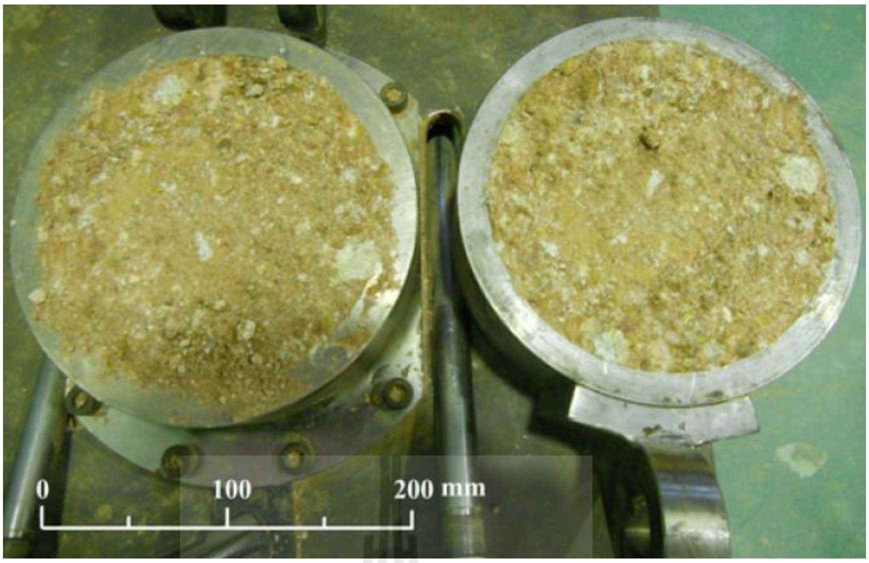
An understanding of the shear strength of soil is necessary in the geotechnical engineering. This is because most geotechnical failures involve a shear type failure of soil. This is due to the nature of soil, which is composed of individual soil particles that slide when the soil is loaded. The shear strength (effective friction angle and cohesion) of soil is required for many difference type of engineering analysis. The most common laboratory test used to determine the shear strength is the direct shear test. The direct shear test, first used by Column in 1766, is the oldest type of shear strength testing equipment. The shear strength of soil can be determined by the commonly corresponding equation. The direct shear test is also the most common laboratory equipment used to obtain the drained shear strength of soil. These tests are performed on different sizes of direct shear boxes (4 in diameter and 7.5 in diameter). The soil sample of preparation for direct shear test has sieved passing sieve no.4 and opening ¾ in. The soil sample was compacted under modified compactive effort energy, as required by ASTM standard. The shearing displacement is constant at 0.1 mm/minutes. Normal stresses are ranging between 351.50 kPa to 1406.02 kPa. The samples after test of both direct shear boxes are shown in Figure 4.7 through 4.10. The examples of direct shear test results are plotted the shear stresses with shear displacement (Figure 4.11 through 4.13). The relationship between shear stress and shear displacement have plotted with varying normal stresses are calculated to find the cohesion and friction angle.

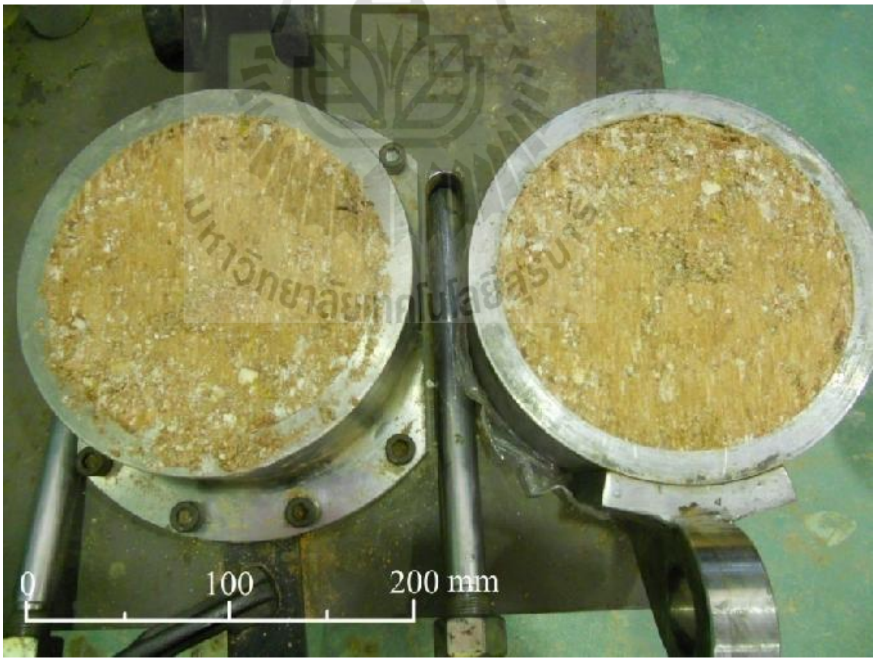
The summary of test results of friction angle is shown in Figure 4.17. The friction angle is decreased when the water content increased. The friction angle obtained from soil sample containing the bigger grain size soil yield the higher friction angle. The summary of test results of cohesion is show in Figure 4.18. In the large-scale direct shear box test results, the cohesion is highest near the optimum water content. In small-scale direct shear box test results have cohesion is decreased when water content increased. Friction angle of compacted soil is decrease with the increasing of water content. The friction angle obtained from small-scale direct shear box are smaller than large scale direct shear box as comparing with the same soil sample.

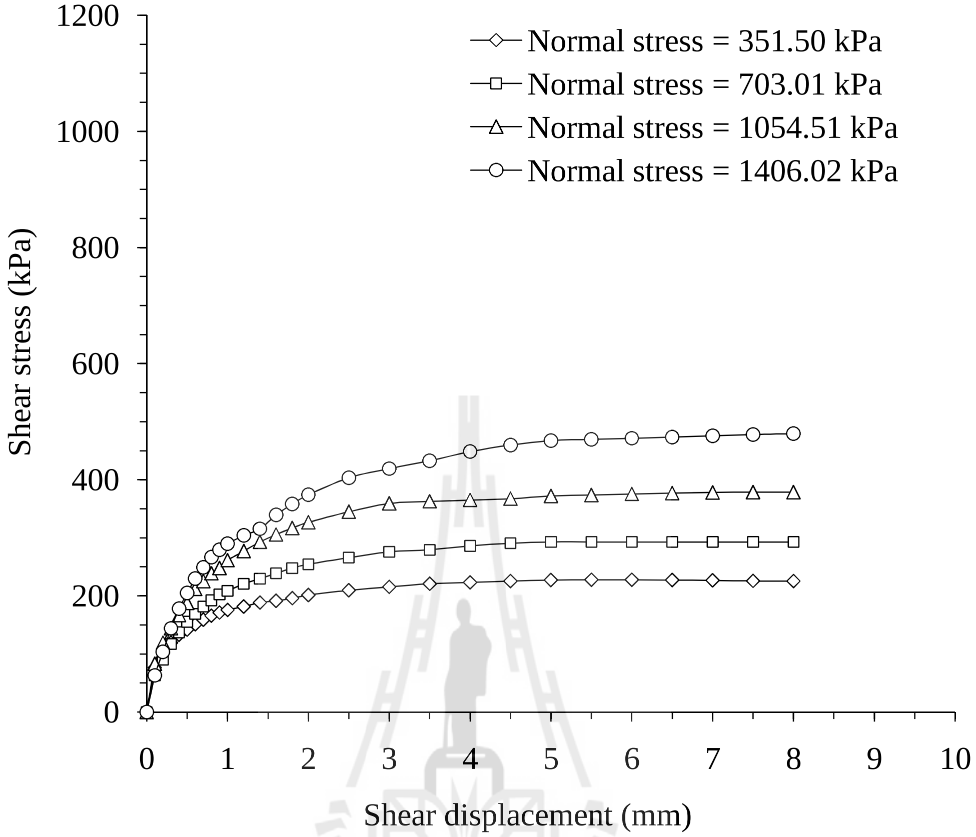
Direct shear box size has been affected for the results of direct shear test because the boundary limiting of shear stress distributions zone. The boundary of shear zone is about 18 times of mean gained size distributions (D_{50}) (Wu et. al, 2008). Small-scale direct shear test is a mold thickness is likely the shear stress distributions zone, the thickness of 20 mm and shear stress distributions zone of 7.2 mm, it has shear stress distributed about 36 percents of shear box thickness (mean grained size of about 0.4 mm). In case of large-scale direct box has shear stress distributed about 4.72 percents of shear box thickness. Cerato and Lutenegger (2006), they reported the box length to median particle diameter (L/D_{50}) has effected to the shear stress and shear deformation, $L/D_{50} \geq 50$ have sufficient particle in the test specimen to allow local rupture and discontinuities to form. Both direct boxes of this research have sufficiently of those relationships. The ratios of shear stress to normal stress with the aspect ratio (H/L) have shown stress ratio increase with an aspect ratio increase (Hight and Leroueil, 2003). Comparison of shear stress with aspect ratio of both direct shear boxes, the shear stress of large-scale direct shear test is higher than small-scale direct shear test, as aspect ratio of large-scale direct shear box is higher than small-


0 50 100 mm

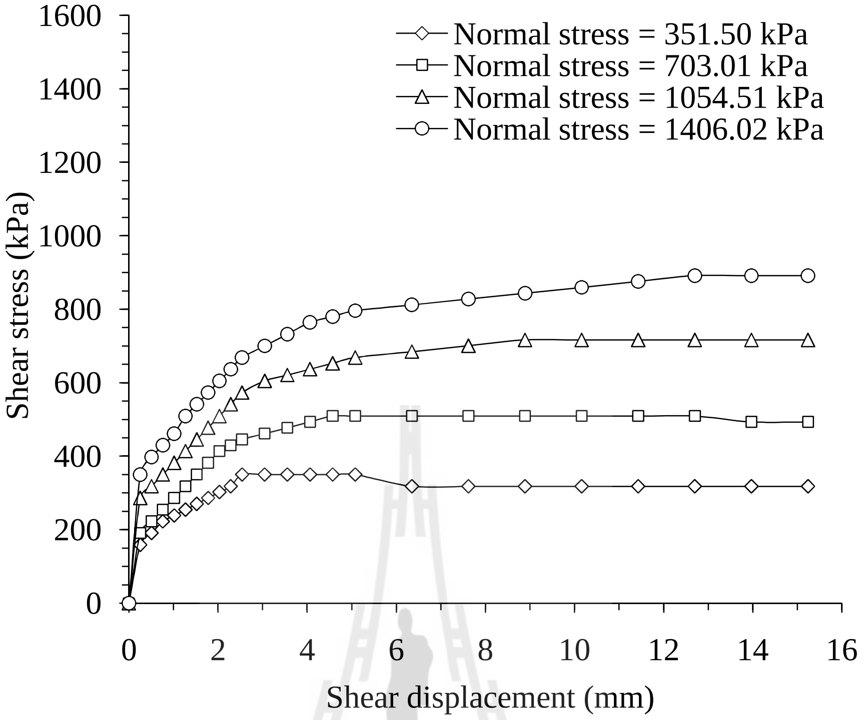

0 50 100 mm


0
100
200 mm

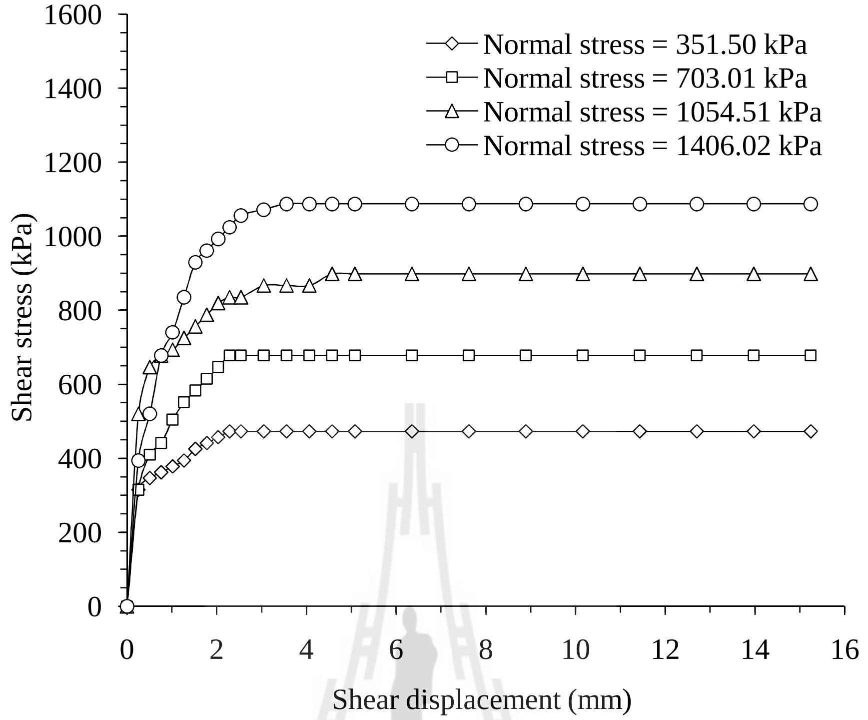

0
100
200 mm



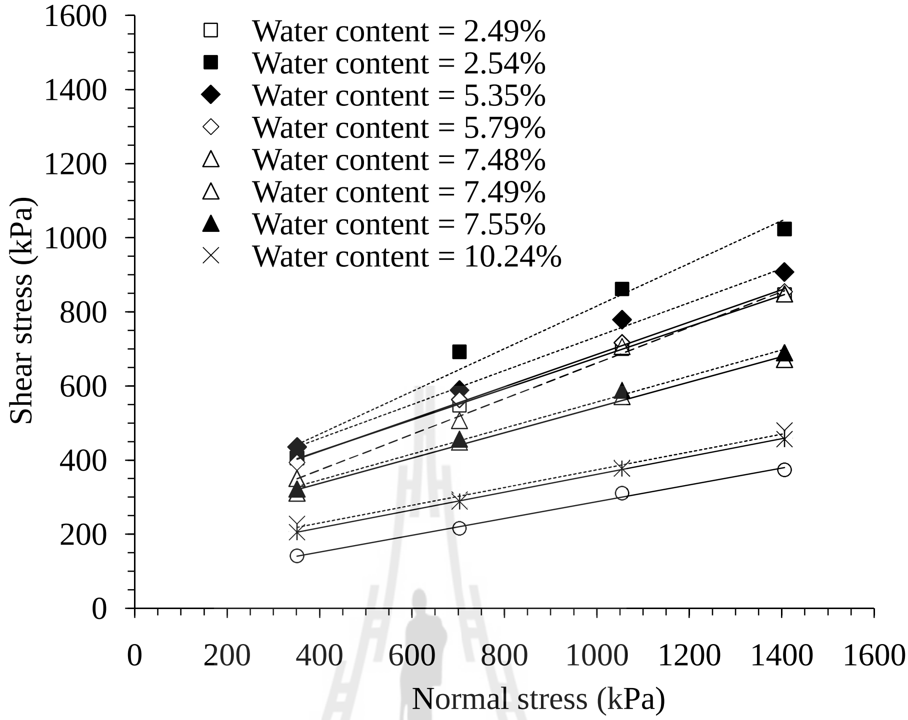
Normal stress = 351.50 kPa
Normal stress = 703.01 kPa
Normal stress = 1054.51 kPa
Normal stress = 1406.02 kPa
Shear stress (kPa)
Shear displacement (mm)
0
200
400
600
800
1000
1200
0
1
2
3
4
5
6
7
8
9
10

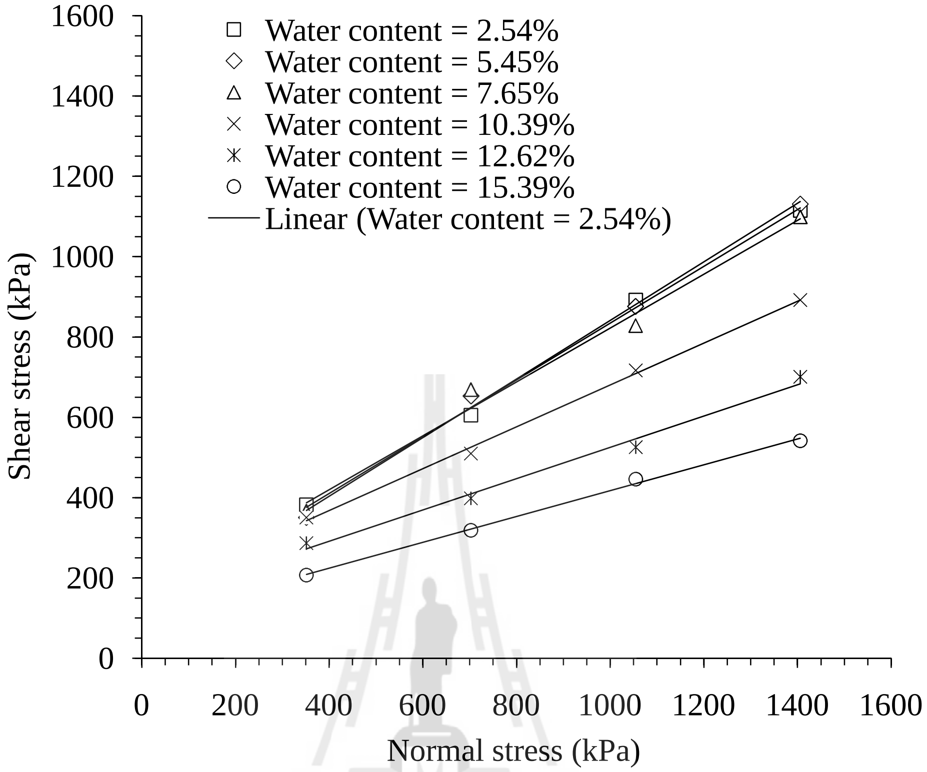


Shear stress (kPa)
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
16
Shear displacement (mm)
Normal stress = 351.50 kPa
Normal stress = 703.01 kPa
Normal stress = 1054.51 kPa
Normal stress = 1406.02 kPa

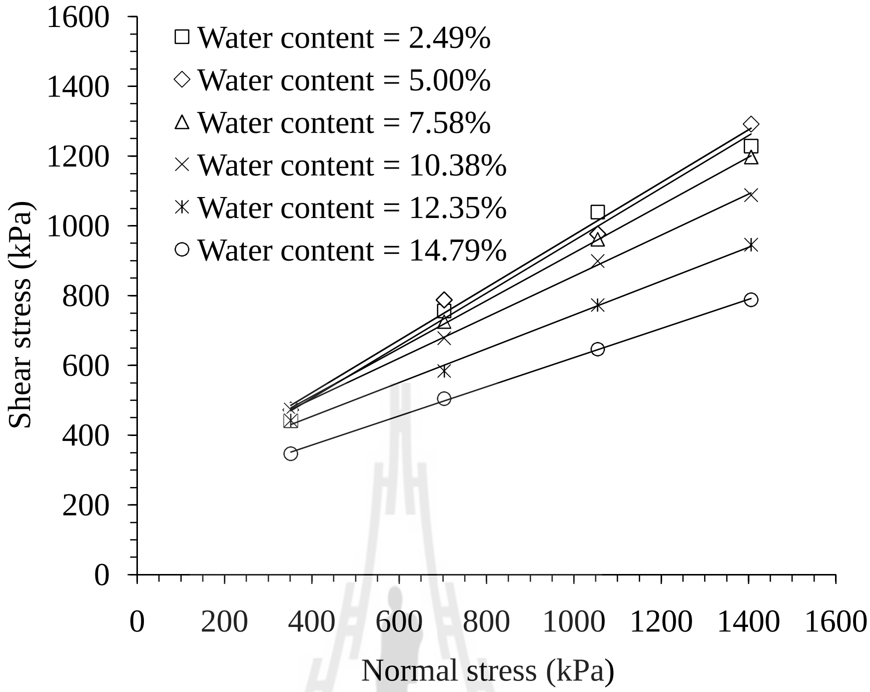


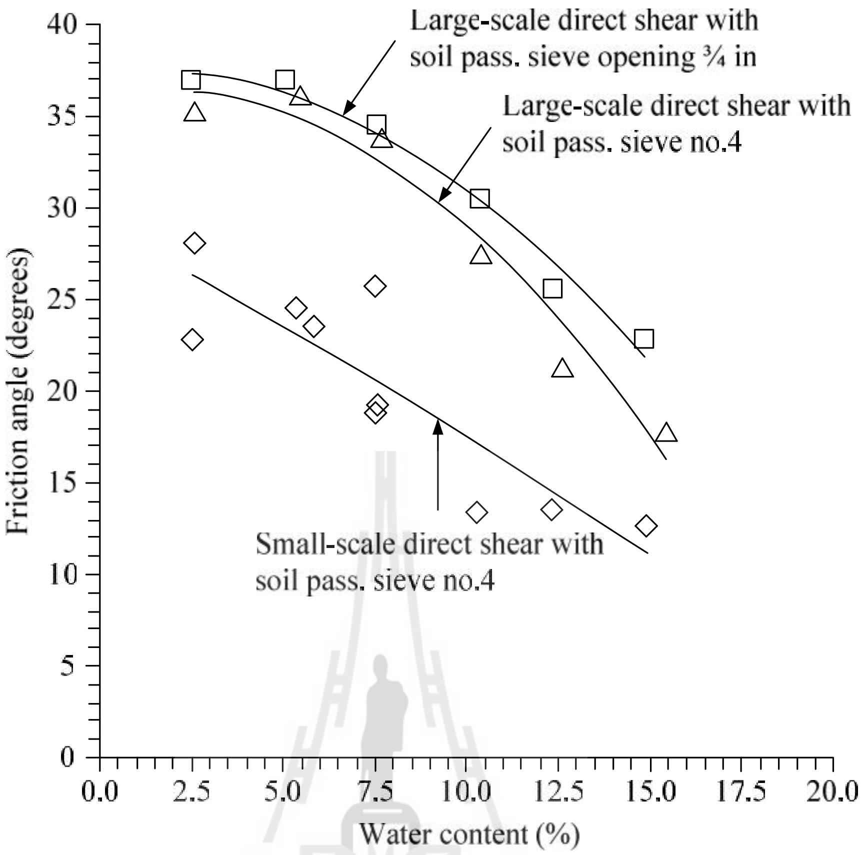
Normal stress = 351.50 kPa
Normal stress = 703.01 kPa
Normal stress = 1054.51 kPa
Normal stress = 1406.02 kPa
Shear stress (kPa)
Shear displacement (mm)
0
200
400
600
800
1000
1200
1400
1600
0
2
4
6
8
10
12
14
16


Water content = 2.49%
Water content = 2.54%
Water content = 5.35%
Water content = 5.79%
Water content = 7.48%
Water content = 7.49%
Water content = 7.55%
Water content = 10.24%
Shear stress (kPa)
Normal stress (kPa)
0
200
400
600
800
1000
1200
1400
1600



1600
1400
1200
1000
800
600
400
200
0
Shear stress (kPa)
0
200
400
600
800
1000
1200
1400
1600
Normal stress (kPa)
Water content = 2.54%
Water content = 5.45%
Water content = 7.65%
Water content = 10.39%
Water content = 12.62%
Water content = 15.39%
Linear (Water content = 2.54%)


Water content = 2.49%
Water content = 5.00%
Water content = 7.58%
Water content = 10.38%
Water content = 12.35%
Water content = 14.79%
Shear stress (kPa)
Normal stress (kPa)
0
200
400
600
800
1000
1200
1400
1600


Large-scale direct shear with
soil pass. sieve opening ¾ in
Large-scale direct shear with
soil pass. sieve no.4
Small-scale direct shear with
soil pass. sieve no.4
Friction angle (degrees)
Water content (%)
0
5
10
15
20
25
30
35
40
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0

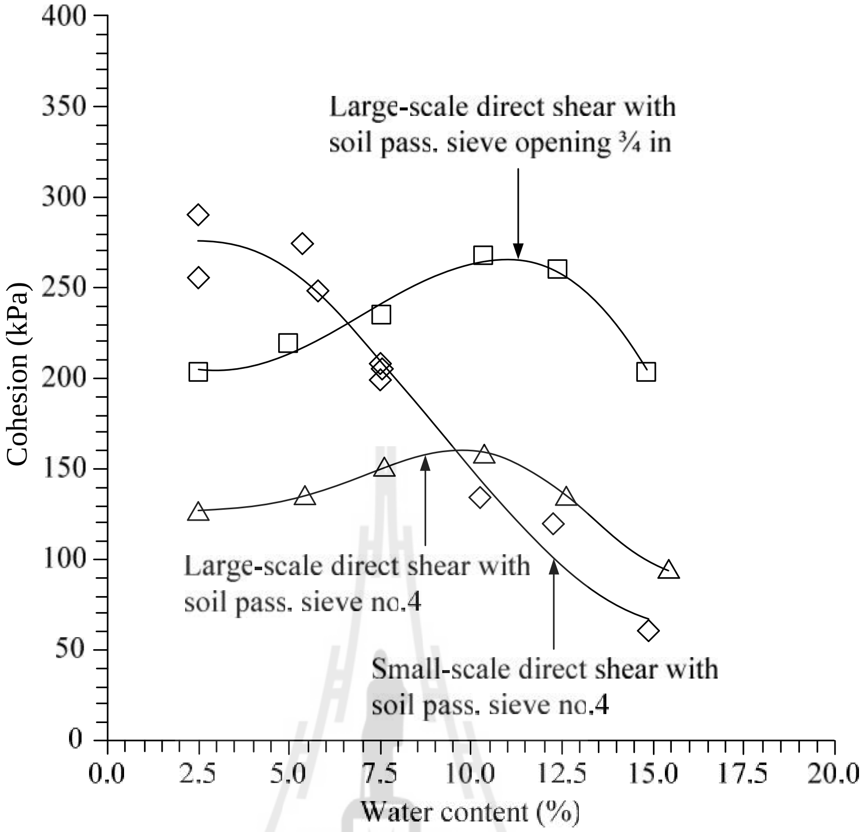

Large-scale direct shear with soil pass. sieve opening ¾ in
Large-scale direct shear with soil pass. sieve no.4
Small-scale direct shear with soil pass. sieve no.4
Cohesion (kPa)
Water content (%)
0
50
100
150
200
250
300
350
400
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0

Table 4.2 Summary of direct shear test results.

	Water content (w) (%)	Friction angle (ϕ) (degree)	Cohesion (c) (kPa)
Small-scale direct shear with soil sample passing sieve no.4	2.49	23	256
	2.54	28	290
	5.35	25	275
	5.79	24	248
	7.48	26	208
	7.49	19	199
	7.55	19	205
	10.24	13	134
	12.26	14	120
	14.89	13	61
Large-scale direct shear with soil sample passing sieve no.4	2.54	35	127
	5.45	36	135
	7.65	34	151
	10.39	27	159
	12.62	21	135
	15.39	18	95
Large-scale direct shear with soil sample passing sieve opening ¾ in	2.49	37	204
	5.00	37	220
	7.58	35	236
	10.38	30	267
	12.35	26	260
	14.79	23	204

CHAPTER V

NUMERICAL ANALYSIS

5.1 Introduction

This chapter is performed to the analysis and design slope stability of in-pit waste pile. The properties of material backfill are considered from laboratory test results to the numerical analysis of slope stability. The slope geometry for this research is performing for education.

5.2 Soil properties

The soil properties are using in the analysis of slope stability are obtained from the laboratory testing; large-scale direct shear test with soil sample passing sieve opening 3/4 in and small-scale direct shear test with soil sample passing sieve no.4. The direct shear test of those is representative shear strength of soil sample on the varying water content. Generally, the shear strength parameters of compacted soil are used in the numerical analysis is using on suitability of the field work. This numerical analysis is selected the shear strength parameters at the optimum water content. The backfill construction of mine rehabilitation, in the field work must be control the dry density is not less than the maximum dry density in the laboratory test. The soil properties for using to numerical analysis by finite different method are including unit weight (γ), Poison's ration (ν), friction angle (ϕ') and cohesion (c'). The comparison, unit weight and Poison's ration are using at the constant value. The shear strength of soil is the effective parameters. The soil parameters are summarized in Table 5.1

Table 5.1 Soil properties for the design in-pit waste pile.

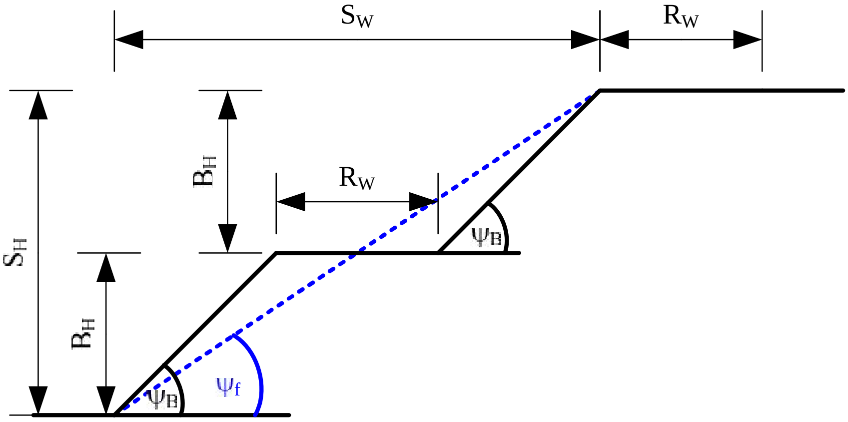
No.	Soil Properties	LSDS parameters	SSDS parameters	Unit
1	Unit Weight (γ)	20	20	kN/m^3
2	Poison's Ratio (ν)	0.35	0.35	-
4	Friction Angle (ϕ′)	32	18	Degrees
5	Cohesion (c′)	260	160	kPa

5.3 Design specification

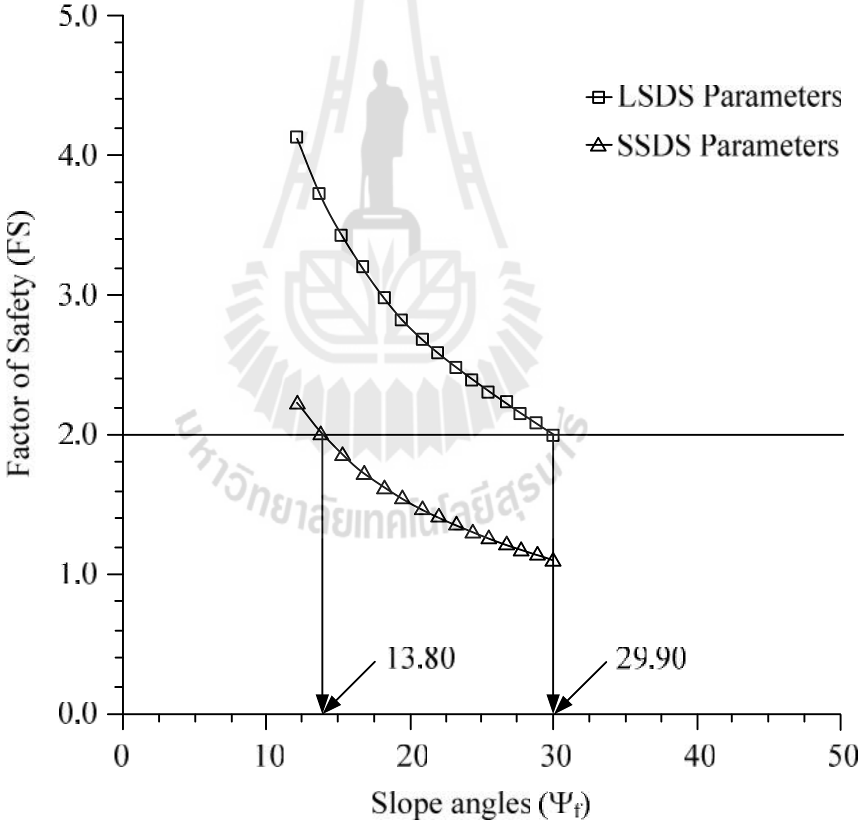
The design specification of in-pit waste pile has defined the factor of safety (FS) is not less than 2.0 for overall slope. Ground water level and construction load are not consideration for calculated. In case of rapid drawdown is not consideration because the material backfill is low plasticity clay, which is low permeability. The numerical analysis model is calculated on plane strain model by FLAC 2D software.

5.4 Slope geometry

The basic geometrical slope design parameters are including berm height (B_H), berm angle (ψ_B), ram width (R_W), slope height (S_H), slope width (S_W) and slope angles (ψ_f). Geometry of modeling for numerical analysis is including berm 20 meters height, ram 20 meters width, berm angle (ψ_B) is various, slope 200 meters height and slope width is various. The overall slope model is added berm and various angles. Typical of geometry of slope stability for numerical analysis is presented in Figure 5.1.



S_W
R_W
B_H
R_W
S_H
B_H
ψ_B
ψ_B
ψ_f



5.0
4.0
3.0
2.0
1.0
0.0
Factor of Safety (FS)
LSDS Parameters
SSDS Parameters
13.80
29.90
0
10
20
30
40
50
Slope angles (Ψf)

Table 5.2 The summary of numerical analysis results.

No.	B_H (m)	R_W (m)	S_H (m)	S_B (m)	ψ_B (degrees)	ψ_f (degrees)	FS LSDS	FS SSDS
1	20	20	200	347.8	50.0	29.90	2.00	1.10
2	20	20	200	363.3	47.5	28.83	2.09	1.14
3	20	20	200	380.0	45.0	27.75	2.14	1.17
4	20	20	200	398.3	42.5	26.67	2.22	1.21
5	20	20	200	418.4	40.0	25.55	2.29	1.26
6	20	20	200	440.6	37.5	24.41	2.38	1.30
7	20	20	200	465.6	35.0	23.25	2.47	1.35
8	20	20	200	493.9	32.5	22.05	2.58	1.40
9	20	20	200	526.4	30.0	20.80	2.69	1.47
10	20	20	200	564.2	27.5	19.52	2.83	1.54
11	20	20	200	608.9	25.0	18.18	2.99	1.62
12	20	20	200	662.8	22.5	16.79	3.19	1.72
13	20	20	200	729.5	20.0	15.33	3.42	1.85
14	20	20	200	814.3	17.5	13.80	3.72	2.01
15	20	20	200	926.4	15.0	12.18	4.12	2.22

CHAPTER VI

DISCUSSION AND CONCLUSION

6.1 Discussions and conclusions

Large-scale direct shear test have been performed to determine the shear strength parameters of backfill material for mine rehabilitation. The properties of soil have tested in the soil mechanics laboratory. Direct shear test have been tested in direct shear box test of two sizes, small-scale direct shear box is 60 mm diameter 30 mm thickness and large-scale direct shear box is 190.5 mm diameter 152.4 mm thickness. Soil sample preparation for testing are normal sieved passing sieve opening ¾ in and sieve no.4 with compacted under modified compaction energy start at low water content at maximum water content that can be compacted. Normal stresses have used from 350.50 kPa to 1406.02 kPa. Shearing rate was used about 1 mm/minutes. The development of large-scale direct shear box test of this research are using for proving of the particle size effect, scale effect and varying water content.

Soil properties are described and summaries in Chapter IV. This soil sample is classified as low plasticity clay (CL). The soil fabrication has containing gravel 25%, sand 10%, silt 37% and clay 28%. The compaction tests are performed on 3 series of soil samples passing sieve no.4 and sieve opening ¾ in with two compaction mold under the modified effort energy. The compaction test results has founded, the mold sizes have no effect on optimum water content, the gravel content have effected on optimum water content and dry density. Consolidation test is performed on the soil sample passive sieve no.4 under modified compactive effort. The maximum past pressure is about 24 kPa.

Direct shear test have been summarized the results of 3 series in chapter IV. The results have been representing the shear strength behavior characteristics of waste rock. The friction angle is decrease with increasing of water content. The friction angle obtained from soil sample containing the bigger grained size soil yield the higher friction angle. In the large-scale direct shear box test results, the cohesion is highest near the optimum water content. In the small-scale direct shear box test results have cohesion is decrease when water content increase. Shear strength is decrease with increase water content. The effected to shear strength of this soil (waste rock) are including the particle size, water content, direct shear box size and relative density.

The design in-pit waste piles are performed for the comparing the shear strength parameters of different sizes of soil sample and direct shear box. The properties of soil are selected of laboratory test. Shear strength parameters is selected of large-scale direct shear test with soil sample passing sieve opening ¾ in and small-scale direct shear test passing sieve no.4. Geometry of slope is fixed berm height and ram width with various berm angles. The numerical analysis for slope stability is used FLAC 2D on Mohr Column failure criteria model with factor of safety not less than 2.0. The results of analysis are founded that slope angle are maximum of 13.80 degrees of small-scale direct shear parameters and 29.90 degrees of large-scale direct shear parameters. The mine rehabilitation for backfill material is using the geometry of slope angle is 29.90 degrees with compacted unit weight not less than 20 kN/m^3. However, in the field work should have control water content not more than the optimum water content.

6.2 Recommendations for future studies

Large-scale direct shear test are well the results. The probability of large-scale direct shear test result is required as follows.

1. Similar test should be performed on the undisturbed sample of coarse grained soil with conformable normal stress and comparison with small-scale direct shear test.

2. Normal stress should be more used of one failure criteria.

3. Large-scale direct shear test should be performed on the disturb sample at various gradation.

REFERENCES

ASTM D422-07. Standard test method for particle-size analysis of soil. **In Annual Book of ASTM Standards (Vol. 04.09) Philadelphia**: American Society for Testing and Materials.

ASTM D854-00. Standard test method for specific gravity of soil solids by water pycnometer. **In Annual Book of ASTM Standards (Vol. 04.08) Philadelphia**: American Society for Testing and Materials.

ASTM D1557-09. Standard test method for laboratory compaction characteristics of soil using modified effort. **In Annual Book of ASTM Standards (Vol. 04.08) Philadelphia**: American Society for Testing and Materials.

ASTM D2435-04. Standard test method for one-dimensional consolidation properties of soil. **In Annual Book of ASTM Standards (Vol. 04.08) Philadelphia**: American Society for Testing and Materials.

ASTM D3080-04. Standard test method for direct shear test of soil under consolidated drained condition. **In Annual Book of ASTM Standards (Vol. 04.08) Philadelphia**: American Society for Testing and Materials.

ASTM D4318-05. Standard test method for liquid limit, plastic limit, and plasticity index of soil. **In Annual Book of ASTM Standards (Vol. 04.08) Philadelphia**: American Society for Testing and Materials.

Bareither, C. A., and Benson, C. H., and Edil, T. B. (2008). Comparison of shear strength of sand backfills measured in small-scale and large-scale direct shear tests. **Canadian Geotechnical Journal** 45: 1224-1236.

Cerato, A. B., and Lutenegger, A. J. (2006). Specimen Size and Scale Effects of Direct Shear Box Tests of Sands. **Geotechnical testing Jounal**. Vol. 29, No.6.

Chinkulkijniwat, A., and Man-Koksung, and E., Uchaipichat, A., and Horpibulsuk, S. (2010). Compaction Characteristics of Non-Gravel and Gravelly Soils Using a Small Compaction Apparatus. **Journal of ASTM International**. Vol. 7, No. 7.

Dadkhah, R., and Ghafoori, M., and Ajalloeian, R., and Lashkaripour, G. R. (2010). The Effect of Scale Direct Shear Test on the Strength Parameters of Clayey Sand in Isfahan City, Iran. **Journal of Applied Sciences** 10(18): 2027-2033.

Garga, V. K., and Madureira, C. T. (1985). Compaction Characteristics of River Terrace Gravel. **Journal of Geotechnical Engineering**. Vol. 111, pp. 987-1007.

Hight, D. W., and Leroueil, S. (2003). Characterisation of Soils for Engineering Purposes. **Proceedings of the Characterisation and Engineering Properties of Natural Soils**. Vol. 1, pp. 255–360.

Nakao, T., and Fityus, S. (2008). Direct Shear testing of a Marginal Material Using a Large Shear Box. **Geotechnical Testing Journal**. Vol. 31, No.5.

Wongtape, A., and Voottipruex, P., and Sridokmai, N. (2007). Efficiency Determination Large Scale Direct Shear Test Apparatus. Mater Thesis, **King Mongkut's Institute of Technology North Bangkok**. Thailand.

Wu, P., and Matsushima, K., and Tatsuoka, F. (2008). Effects of Specimen Size and Some Other Factors on the Strength and Deformation of Granular Soil in Direct Shear Tests. **Geotechnical Testing Journal**. Vol. 31, No.1.

Yazdanjou, V., and Eshkevari, S. N., and Hamidi, A. (2008). Effect of Gravel Content on the Shear Behavior of Sandy Soils. **The 4th National Conference on Civil Engineering**, University of Tehran.

APPENDIX A

LABORATORY TEST RESULTS

Table A.1 Natural water content.

Container No. :	1	2	3	4	5
Weight of Container + Wet soil (g.)	218.85	205.99	165.90	215.54	201.46
Weight of Container + Dry soil (g.)	199.67	190.73	151.17	197.91	184.77
Weight of Container (g.)	32.33	31.82	31.74	33.81	32.84
Weight of Dry Soil (g.)	167.34	158.91	119.43	164.10	151.93
Weight of Water (g.)	19.18	15.26	14.73	17.63	16.69
Water Content (%)	11.46	9.60	12.33	10.74	10.99
Average Water Content (%)	11.03				

Table A.2 Liquid limit test of sample no.1.

Number of Blows		11	18	26	47
Container number		1	2	3	4
Weight of Wet Soil + Container	(g)	35.60	42.01	37.84	43.14
Weight of Dry Soil + Container	(g)	34.50	39.46	36.35	41.05
Weight of Water	(g)	1.10	2.55	1.49	2.09
Weight of Container	(g)	30.99	33.90	31.28	32.99
Weight Of Dry Soil	(g)	3.51	8.47	5.36	10.06
Water Content	(%)	31.34	30.11	27.80	20.78

Table A.3 Plastic limit test of sample no.1.

Container number		1	2	3	4
Weight of Wet Soil + Container	(g)	36.24	28.56	36.32	36.13
Weight of Dry Soil + Container	(g)	35.86	28.23	35.95	35.71
Weight of Water	(g)	0.38	0.33	0.37	0.42
Weight of Container	(g)	33.23	26.14	33.59	33.02
Weight Of Dry Soil	(g)	2.63	2.09	2.36	2.69
Water Content	(%)	14.45	15.79	15.68	15.61

Table A.4 Liquid limit test of sample no.2.

Number of Blows		15	21	26	43
Container number		1	2	3	4
Weight of Wet Soil + Container	(g)	43.06	43.02	39.98	38.93
Weight of Dry Soil + Container	(g)	40.35	40.46	38.12	37.42
Weight of Water	(g)	2.71	2.56	1.86	1.51
Weight of Container	(g)	34.00	33.39	31.81	31.55
Weight Of Dry Soil	(g)	9.36	9.47	7.13	6.43
Water Content	(%)	28.95	27.03	26.09	23.48

Table A.5 Plastic limit test of sample no.2.

Container number		1	2	3	4
Weight of Wet Soil + Container	(g)	36.84	36.87	38.52	34.28
Weight of Dry Soil + Container	(g)	36.35	36.53	37.93	33.72
Weight of Water	(g)	0.49	0.34	0.59	0.56
Weight of Container	(g)	33.28	34.15	34.15	30.5
Weight Of Dry Soil	(g)	3.07	2.38	3.78	3.22
Water Content	(%)	15.96	14.29	15.61	17.39

Table A.6 Specific gravity test.

Test no.		1	2	3
Tempurature	(c)	31.00	31.00	31.00
Weight of Flask + Water + Soil,W1	(g)	679.40	686.82	681.01
Weight of Flask + Water (FromCalibration),W2	(g)	651.00	651.00	651.00
Weight of Dry Soil + Container	(g)	661.30	655.00	651.04
Weight of Container	(g)	616.76	599.13	604.15
Weight of Dry soil,Ws	(g)	44.54	55.87	46.89
Specific Gravity of Water at T,G_T		0.9956	0.9956	0.9956
Specific Gravity of Soil		2.75	2.77	2.77
Average Specific Gravity of Soil			2.76	

Table A.7 Sieve analysis test result.

Seive No.	Sieve Opening (mm)	Weight of Sieve (g)	Weight of Sieve + Soil (g)	Weight of Soil Retained (g)	Comulative Retained (g)	Comulative Retained (%)	Percent Finer (%)
3/4	19.000	109.50	138.09	28.59	28.59	2.51	97.49
3/8	9.500	100.93	178.54	77.61	106.20	9.33	90.67
4	4.750	102.31	191.36	89.05	195.25	17.16	82.84
10	2.000	98.56	184.99	86.43	281.68	24.75	75.25
20	0.850	98.91	160.05	61.14	342.82	30.13	69.87
40	0.425	113.62	162.24	48.62	391.44	34.40	65.60
60	0.250	92.01	115.68	23.67	415.11	36.48	63.52
100	0.150	118.63	155.71	37.08	452.19	39.74	60.26
200	0.075	117.78	189.07	71.29	523.48	46.00	54.00
Pan		4278.69	4893.13	614.44	1137.92	100.00	0.00

Table A.8 Hydrometer analysis test result.

Elapsed time (min)	r	R=1000(r-1)	r_w	R_w=1000(r_w-1)	Temp. (c^o)	R-R_w	N=K1(R-R_w) (%)	R_c	Z_r (cm)	sqrt(Zr/t)	D=K2sqrt(Z_r/t) (mm)	N' (%)
0.25	1.0250	25.0	0.9960	-4.0	30	29.0	124.88	29.50	9.95	6.31	0.079	54.32
0.50	1.0230	23.0	0.9960	-4.0		27.0	116.27	27.50	10.75	4.64	0.058	50.58
1.00	1.0220	22.0	0.9960	-4.0		26.0	111.96	26.50	11.15	3.34	0.042	48.70
2.00	1.0205	20.5	0.9960	-4.0		24.5	105.51	25.00	11.75	2.42	0.030	45.89
0.25	1.0250	25.0	0.9960	-4.0	30	29.0	124.88	29.50	9.95	6.31	0.079	54.32
0.50	1.0240	24.0	0.9960	-4.0		28.0	120.58	28.50	10.35	4.55	0.057	52.45
1.00	1.0230	23.0	0.9960	-4.0		27.0	116.27	27.50	10.75	3.28	0.041	50.58
2.00	1.0210	21.0	0.9960	-4.0		25.0	107.66	25.50	11.55	2.40	0.030	46.83
4.00	1.0200	20.0	0.9960	-4.0		24.0	103.35	24.50	10.70	1.64	0.020	44.96
8.00	1.0190	19.0	0.9960	-4.0		23.0	99.05	23.50	11.10	1.18	0.015	43.08
16.00	1.0170	17.0	0.9960	-4.0		21.0	90.43	21.50	11.90	0.86	0.011	39.34
32.00	1.0150	15.0	0.9960	-4.0		19.0	81.82	19.50	12.70	0.63	0.008	35.59
64.00	1.0140	14.0	0.9960	-4.0		18.0	77.51	18.50	13.10	0.45	0.006	33.72
128.00	1.0130	13.0	0.9960	-4.0		17.0	73.21	17.50	13.50	0.32	0.004	31.85
256.00	1.0120	12.0	0.9960	-4.0		16.0	68.90	16.50	13.90	0.23	0.003	29.97
512.00	1.0110	11.0	0.9960	-4.0		15.0	64.60	15.50	14.30	0.17	0.002	28.10
1024.00	1.0100	10.0	0.9960	-4.0		14.0	60.29	14.50	14.70	0.12	0.001	26.23
2048.00	1.0090	9.0	0.9960	-4.0		13.0	55.98	13.50	15.10	0.09	0.001	24.35
4096.00	1.0080	8.0	0.9960	-4.0		12.0	51.68	12.50	15.50	0.06	0.001	22.48
8192.00	1.0075	7.5	0.9960	-4.0		11.5	49.52	12.00	15.70	0.04	0.001	21.54
16384.00	1.0075	7.5	0.9960	-4.0		11.5	49.52	12.00	15.70	0.03	0.000	21.54

Table A.9 Compaction test result of standard mold 4 in with soil sample passing sieve no.4.

Test No.		1	2	3	4	5	6	7
Amount of Water Added	(g)							
Weight of Wet Soil + Mould	(g)	11045	11280	11363	11230	11020	10858	10515
Weight of Mould	(g)	6407	6407	6407	6407	6407	6335	6335
Weight of Wet Soil	(g)	4638	4873	4956	4823	4613	4523	4180
Wet Density	(g/cm^3)	2.002	2.103	2.139	2.082	1.991	1.952	1.804
Dry Density	(g/cm^3)	1.877	1.939	1.936	1.839	1.726	1.844	1.736
Container No.		1	2	3	4	5	6	7
Weight of Wet Soil + Container	(g)	129.16	151.08	154.05	159.15	193.02	161.91	153.02
Weight of Dry Soil + Container	(g)	123.18	141.74	142.5	144.33	171.56	154.77	148.46
Weight of Water	(g)	5.98	9.34	11.55	14.82	21.46	7.14	4.56
Weight 0f Container	(g)	33.49	31.33	32.31	31.89	31.89	33.81	33.18
Weight of Dry Soil	(g)	89.69	110.41	110.19	112.44	139.67	120.96	115.28
Water Content	(%)	6.667	8.459	10.482	13.180	15.365	5.903	3.956

Table A.10 Compaction test result of large mold 7.5 in with soil sample passing sieve no.4.

Test No.		1	2	3	4	5	6
Amount of Water Added	(g)						
Weight of Wet Soil + Mould	(g)	36200	36700	37200	37300	37100	36900
Weight of Mould	(g)	32250	32250	32250	32250	32250	32250
Weight of Wet Soil	(g)	3950	4450	4950	5050	4850	4650
Wet Density	(g/cm^3)	1.705	1.921	2.137	2.180	2.094	2.007
Dry Density	(g/cm^3)	1.663	1.822	1.985	1.975	1.859	1.739
Container No.							
Weight of Wet Soil + Container	(g)	223.90	207.98	188.63	188.13	235.46	181.69
Weight of Dry Soil + Container	(g)	219.18	198.94	177.52	173.53	212.83	161.85
Weight of Water	(g)	4.72	9.04	11.11	14.6	22.63	19.84
Weight 0f Container	(g)	33.35	33.13	32.43	32.85	33.48	32.98
Weight of Dry Soil	(g)	185.83	165.81	145.09	140.68	179.35	128.87
Water Content	(%)	2.540	5.452	7.657	10.378	12.618	15.395

Table A.11 Compaction test result of large mold 7.5 in with soil sample passing sieve opening ¾ in.

Test No.		1	2	3	4	5	6
Amount of Water Added	(g)						
Weight of Wet Soil + Mould	(g)	36400	37100	37300	37400	37300	37000
Weight of Mould	(g)	32250	32250	32250	32250	32250	32250
Weight of Wet Soil	(g)	4150	4850	5050	5150	5050	4750
Wet Density	(g/cm^3)	1.791	2.094	2.180	2.223	2.180	2.050
Dry Density	(g/cm^3)	1.748	1.984	2.025	2.014	1.936	1.777
Container No.							
Weight of Wet Soil + Container	(g)	223.81	208.12	188.62	188.15	235.47	181.69
Weight of Dry Soil + Container	(g)	219.18	198.94	177.52	173.53	212.83	161.85
Weight of Water	(g)	4.63	9.18	11.1	14.62	22.64	19.84
Weight 0f Container	(g)	33.35	33.13	32.43	32.85	33.48	32.98
Weight of Dry Soil	(g)	185.83	165.81	145.09	140.68	179.35	128.87
Water Content	(%)	2.492	5.536	7.650	10.392	12.623	15.395

Table A.12 Consolidation test result.

Applied Pressure (kPa)	Scale Load (kg)	Final Dial. Reading x0.002 (mm)	Acc. Dial. Change (cm)	Sample Height 2H,cm	Void Height (2H-Hs,cm)	Void Ratio (e)	Ave. Sample Height (2Hav,cm)
0	0.00	0	0.000	1.960	0.615	0.457	
10	3.88	46	0.009	1.951	0.606	0.451	1.955
20	7.78	90	0.018	1.942	0.597	0.444	1.946
40	15.56	440	0.088	1.872	0.527	0.392	1.907
80	31.12	752	0.150	1.810	0.465	0.346	1.841
160	62.23	1090	0.218	1.742	0.397	0.295	1.776
320	124.46	1428	0.286	1.674	0.330	0.245	1.708
640	248.92	1705	0.341	1.619	0.274	0.204	1.647

Table A.13 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 2.56% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm.	Load reading (div.)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-1	-0.01	240	33.60	108.20
20	0.20	-2	-0.02	300	42.00	135.25
30	0.30	-3	-0.03	320	44.80	144.27
40	0.40	-3	-0.03	360	50.40	162.30
50	0.50	-5	-0.05	390	54.60	175.82
60	0.60	-8	-0.08	410	57.40	184.84
70	0.70	-9	-0.09	430	60.20	193.86
80	0.80	-10	-0.10	445	62.30	200.62
90	0.90	-10	-0.10	455	63.70	205.13
100	1.00	-10	-0.10	460	64.40	207.38
120	1.20	-9	-0.09	480	67.20	216.40
140	1.40	-9	-0.09	491	68.74	221.36
160	1.60	-8	-0.08	495	69.30	223.16
180	1.80	-7	-0.07	496	69.44	223.61
200	2.00	-7	-0.07	515	72.10	232.18
250	2.50	-7	-0.07	580	81.20	261.48
300	3.00	-7	-0.07	635	88.90	286.28
350	3.50	-7	-0.07	690	96.60	311.07
400	4.00	-6	-0.06	735	102.90	331.36
450	4.50	-6	-0.06	777	108.78	350.30
500	5.00	-6	-0.06	817	114.38	368.33
550	5.50	-6	-0.06	848	118.72	382.30
600	6.00	-7	-0.07	868	121.52	391.32
650	6.50	-8	-0.08	885	123.90	398.98
700	7.00	-8	-0.08	896	125.44	403.94
750	7.50	-8	-0.08	899	125.86	405.30
800	8.00	-9	-0.09	900	126.00	405.75
850	8.50	-10	-0.10	900	126.00	405.75
900	9.00	-10	-0.10	900	126.00	405.75

Table A.14 Small-sacle direct shear test with soil sample passing sieve no.4 at water content about 2.37% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (div.)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-2	-0.02	97	13.58	43.73
20	0.20	-4	-0.04	284	39.76	128.04
30	0.30	-5	-0.05	370	51.80	166.81
40	0.40	-7	-0.07	422	59.08	190.25
50	0.50	-8	-0.08	463	64.82	208.73
60	0.60	-10	-0.10	497	69.58	224.06
70	0.70	-10	-0.10	508	71.12	229.02
80	0.80	-10	-0.10	523	73.22	235.78
90	0.90	-10	-0.10	542	75.88	244.35
100	1.00	-10	-0.10	591	82.74	266.44
120	1.20	-10	-0.10	648	90.72	292.14
140	1.40	-11	-0.11	689	96.46	310.62
160	1.60	-11	-0.11	720	100.80	324.60
180	1.80	-11	-0.11	762	106.68	343.53
200	2.00	-11	-0.11	837	117.18	377.34
250	2.50	-11	-0.11	960	134.40	432.80
300	3.00	-11	-0.11	1071	149.94	482.84
350	3.50	-11	-0.11	1150	161.00	518.45
400	4.00	-11	-0.11	1175	164.50	529.73
450	4.50	-11	-0.11	1185	165.90	534.23
500	5.00	-11	-0.11	1195	167.30	538.74
550	5.50	-11	-0.11	1205	168.70	543.25
600	6.00	-11	-0.11	1215	170.10	547.76
650	6.50	-11	-0.11	1215	170.10	547.76
700	7.00	-11	-0.11	1215	170.10	547.76
750	7.50	-11	-0.11	1215	170.10	547.76
800	8.00	-11	-0.11	1215	170.10	547.76
850	8.50	-11	-0.11	1215	170.10	547.76
900	9.00	-11	-0.11	1215	170.10	547.76

Table A.15 Small-sacle direct shear test with soil sample passing sieve no.4 at water content about 2.57% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (div.)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-4	-0.04	230	32.20	103.69
20	0.20	-7	-0.07	346	48.44	155.99
30	0.30	-9	-0.09	430	60.20	193.86
40	0.40	-11	-0.11	515	72.10	232.18
50	0.50	-10	-0.10	580	81.20	261.48
60	0.60	-10	-0.10	640	89.60	288.53
70	0.70	-10	-0.10	685	95.90	308.82
80	0.80	-10	-0.10	730	102.20	329.11
90	0.90	-9	-0.09	775	108.50	349.39
100	1.00	-9	-0.09	800	112.00	360.66
120	1.20	-8	-0.08	820	114.80	369.68
140	1.40	-8	-0.08	840	117.60	378.70
160	1.60	-8	-0.08	850	119.00	383.21
180	1.80	-8	-0.08	860	120.40	387.71
200	2.00	-8	-0.08	935	130.90	421.53
250	2.50	-8	-0.08	1065	149.10	480.13
300	3.00	-8	-0.08	1140	159.60	513.95
350	3.50	-8	-0.08	1205	168.70	543.25
400	4.00	-8	-0.08	1260	176.40	568.05
450	4.50	-9	-0.09	1304	182.56	587.88
500	5.00	-10	-0.10	1338	187.32	603.21
550	5.50	-11	-0.11	1415	198.10	637.92
600	6.00	-12	-0.12	1455	203.70	655.96
650	6.50	-13	-0.13	1516	212.24	683.46
700	7.00	-14	-0.14	1555	217.70	701.04
750	7.50	-15	-0.15	1555	217.70	701.04
800	8.00	-16	-0.16	1555	217.70	701.04
850	8.50	-17	-0.17	1555	217.70	701.04
900	9.00	-18	-0.18	1555	217.70	701.04

Table A.16 Small-sacle direct shear test with soil sample passing sieve no.4 at water content about 2.45% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (div.)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-7	-0.07	410	57.40	184.84
20	0.20	-10	-0.10	520	72.80	234.43
30	0.30	-12	-0.12	590	82.60	265.99
40	0.40	-13	-0.13	660	92.40	297.55
50	0.50	-13	-0.13	705	98.70	317.84
60	0.60	-13	-0.13	708	99.12	319.19
70	0.70	-15	-0.15	730	102.20	329.11
80	0.80	-16	-0.16	770	107.80	347.14
90	0.90	-17	-0.17	835	116.90	376.44
100	1.00	-18	-0.18	935	130.90	421.53
120	1.20	-20	-0.20	943	132.02	425.13
140	1.40	-19	-0.19	1025	143.50	462.10
160	1.60	-19	-0.19	1098	153.72	495.01
180	1.80	-19	-0.19	1160	162.40	522.96
200	2.00	-19	-0.19	1215	170.10	547.76
250	2.50	-19	-0.19	1355	189.70	610.88
300	3.00	-19	-0.19	1465	205.10	660.47
350	3.50	-21	-0.21	1545	216.30	696.53
400	4.00	-23	-0.23	1645	230.30	741.62
450	4.50	-23	-0.23	1720	240.80	775.43
500	5.00	-23	-0.23	1780	249.20	802.48
550	5.50	-23	-0.23	1820	254.80	820.51
600	6.00	-23	-0.23	1845	258.30	831.78
650	6.50	-24	-0.24	1865	261.10	840.80
700	7.00	-25	-0.25	1878	262.92	846.66
750	7.50	-25	-0.25	1879	263.06	847.11
800	8.00	-25	-0.25	1879	263.06	847.11
850	8.50	-26	-0.26	1879	263.06	847.11
900	9.00	-26	-0.26	1879	263.06	847.11

Table A.17 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 5.89% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (div.)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	0	0.00	118	16.52	53.20
20	0.20	-1	-0.01	242	33.88	109.10
30	0.30	-2	-0.02	259	36.26	116.77
40	0.40	-3	-0.03	342	47.88	154.18
50	0.50	-4	-0.04	445	62.30	200.62
60	0.60	-5	-0.05	480	67.20	216.40
70	0.70	-6	-0.06	525	73.50	236.69
80	0.80	-6	-0.06	549	76.86	247.51
90	0.90	-7	-0.07	562	78.68	253.37
100	1.00	-8	-0.08	577	80.78	260.13
120	1.20	-10	-0.10	602	84.28	271.40
140	1.40	-11	-0.11	625	87.50	281.77
160	1.60	-12	-0.12	645	90.30	290.79
180	1.80	-12	-0.12	667	93.38	300.70
200	2.00	-12	-0.12	688	96.32	310.17
250	2.50	-12	-0.12	732	102.48	330.01
300	3.00	-11	-0.11	769	107.66	346.69
350	3.50	-10	-0.10	799	111.86	360.21
400	4.00	-8	-0.08	823	115.22	371.03
450	4.50	-6	-0.06	835	116.90	376.44
500	5.00	-6	-0.06	845	118.30	380.95
550	5.50	-6	-0.06	855	119.70	385.46
600	6.00	-6	-0.06	867	121.38	390.87
650	6.50	-6	-0.06	872	122.08	393.12
700	7.00	-6	-0.06	873	122.22	393.57
750	7.50	-6	-0.06	874	122.36	394.03
800	8.00	-6	-0.06	874	122.36	394.03
850	8.50	-6	-0.06	874	122.36	394.03
900	9.00	-6	-0.06	874	122.36	394.03

Table A.18 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 5.51% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (div.)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	4	0.04	120	16.80	54.10
20	0.20	2	0.02	220	30.80	99.18
30	0.30	0	0.00	285	39.90	128.49
40	0.40	-2	-0.02	350	49.00	157.79
50	0.50	-3	-0.03	400	56.00	180.33
60	0.60	-4	-0.04	455	63.70	205.13
70	0.70	-5	-0.05	505	70.70	227.67
80	0.80	-6	-0.06	550	77.00	247.96
90	0.90	-7	-0.07	595	83.30	268.24
100	1.00	-8	-0.08	640	89.60	288.53
120	1.20	-9	-0.09	720	100.80	324.60
140	1.40	-10	-0.10	795	111.30	358.41
160	1.60	-11	-0.11	855	119.70	385.46
180	1.80	-12	-0.12	903	126.42	407.10
200	2.00	-12	-0.12	950	133.00	428.29
250	2.50	-13	-0.13	1040	145.60	468.86
300	3.00	-15	-0.15	1113	155.82	501.77
350	3.50	-16	-0.16	1162	162.68	523.86
400	4.00	-18	-0.18	1186	166.04	534.68
450	4.50	-21	-0.21	1205	168.70	543.25
500	5.00	-24	-0.24	1250	175.00	563.54
550	5.50	-24	-0.24	1250	175.00	563.54
600	6.00	-24	-0.24	1250	175.00	563.54
650	6.50	-24	-0.24	1250	175.00	563.54
700	7.00	-24	-0.24	1250	175.00	563.54
750	7.50	-24	-0.24	1250	175.00	563.54
800	8.00	-24	-0.24	1250	175.00	563.54
850	8.50	-24	-0.24	1250	175.00	563.54
900	9.00	-24	-0.24	1250	175.00	563.54

Table A.19 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 5.79% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-4	-0.04	280	39.20	126.23
20	0.20	-6	-0.06	370	51.80	166.81
30	0.30	-9	-0.09	445	62.30	200.62
40	0.40	-10	-0.10	520	72.80	234.43
50	0.50	-11	-0.11	585	81.90	263.74
60	0.60	-12	-0.12	635	88.90	286.28
70	0.70	-14	-0.14	685	95.90	308.82
80	0.80	-15	-0.15	735	102.90	331.36
90	0.90	-15	-0.15	775	108.50	349.39
100	1.00	-16	-0.16	815	114.10	367.43
120	1.20	-18	-0.18	892	124.88	402.14
140	1.40	-20	-0.20	965	135.10	435.05
160	1.60	-20	-0.20	1035	144.90	466.61
180	1.80	-20	-0.20	1110	155.40	500.42
200	2.00	-20	-0.20	1180	165.20	531.98
250	2.50	-21	-0.21	1305	182.70	588.33
300	3.00	-22	-0.22	1400	196.00	631.16
350	3.50	-22	-0.22	1468	205.52	661.82
400	4.00	-20	-0.20	1520	212.80	685.26
450	4.50	-15	-0.15	1560	218.40	703.30
500	5.00	-15	-0.15	1580	221.20	712.31
550	5.50	-18	-0.18	1587	222.18	715.47
600	6.00	-20	-0.20	1590	222.60	716.82
650	6.50	-20	-0.20	1590	222.60	716.82
700	7.00	-20	-0.20	1590	222.60	716.82
750	7.50	-20	-0.20	1590	222.60	716.82
800	8.00	-20	-0.20	1590	222.60	716.82
850	8.50	-20	-0.20	1590	222.60	716.82
900	9.00	-20	-0.20	1590	222.60	716.82

Table A.20 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 5.95% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-4	-0.04	355	49.70	160.04
20	0.20	-7	-0.07	485	67.90	218.65
30	0.30	-9	-0.09	590	82.60	265.99
40	0.40	-10	-0.10	670	93.80	302.06
50	0.50	-12	-0.12	750	105.00	338.12
60	0.60	-13	-0.13	830	116.20	374.19
70	0.70	-14	-0.14	870	121.80	392.22
80	0.80	-15	-0.15	920	128.80	414.76
90	0.90	-16	-0.16	965	135.10	435.05
100	1.00	-17	-0.17	1010	141.40	455.34
120	1.20	-18	-0.18	1095	153.30	493.66
140	1.40	-19	-0.19	1170	163.80	527.47
160	1.60	-20	-0.20	1240	173.60	559.03
180	1.80	-20	-0.20	1310	183.40	590.59
200	2.00	-21	-0.21	1380	193.20	622.15
250	2.50	-21	-0.21	1503	210.42	677.60
300	3.00	-21	-0.21	1590	222.60	716.82
350	3.50	-20	-0.20	1660	232.40	748.38
400	4.00	-20	-0.20	1725	241.50	777.68
450	4.50	-22	-0.22	1770	247.80	797.97
500	5.00	-25	-0.25	1820	254.80	820.51
550	5.50	-28	-0.28	1845	258.30	831.78
600	6.00	-30	-0.30	1880	263.20	847.56
650	6.50	-30	-0.30	1895	265.30	854.32
700	7.00	-30	-0.30	1895	265.30	854.32
750	7.50	-30	-0.30	1895	265.30	854.32
800	8.00	-30	-0.30	1895	265.30	854.32
850	8.50	-30	-0.30	1895	265.30	854.32
900	9.00	-30	-0.30	1895	265.30	854.32

Table A.21 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 7.26% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-1	-0.01	237	33.18	106.85
20	0.20	-1	-0.01	255	35.70	114.96
30	0.30	-1	-0.01	289	40.46	130.29
40	0.40	-1	-0.01	300	42.00	135.25
50	0.50	-1	-0.01	342	47.88	154.18
60	0.60	0	0.00	381	53.34	171.77
70	0.70	1	0.01	390	54.60	175.82
80	0.80	4	0.04	401	56.14	180.78
90	0.90	5	0.05	408	57.12	183.94
100	1.00	6	0.06	415	58.10	187.09
120	1.20	8	0.08	430	60.20	193.86
140	1.40	8	0.08	445	62.30	200.62
160	1.60	8	0.08	454	63.56	204.68
180	1.80	8	0.08	465	65.10	209.64
200	2.00	7	0.07	485	67.90	218.65
250	2.50	5	0.05	520	72.80	234.43
300	3.00	5	0.05	550	77.00	247.96
350	3.50	4	0.04	575	80.50	259.23
400	4.00	4	0.04	600	84.00	270.50
450	4.50	4	0.04	623	87.22	280.87
500	5.00	4	0.04	644	90.16	290.33
550	5.50	4	0.04	674	94.36	303.86
600	6.00	4	0.04	688	96.32	310.17
650	6.50	4	0.04	690	96.60	311.07
700	7.00	4	0.04	690	96.60	311.07
750	7.50	4	0.04	690	96.60	311.07
800	8.00	4	0.04	690	96.60	311.07
850	8.50	4	0.04	690	96.60	311.07
900	9.00	4	0.04	690	96.60	311.07

Table A.22 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 7.96% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-4	-0.04	260	36.40	117.22
20	0.20	-6	-0.06	370	51.80	166.81
30	0.30	-7	-0.07	465	65.10	209.64
40	0.40	-8	-0.08	545	76.30	245.70
50	0.50	-9	-0.09	615	86.10	277.26
60	0.60	-9	-0.09	675	94.50	304.31
70	0.70	-9	-0.09	720	100.80	324.60
80	0.80	-9	-0.09	757	105.98	341.28
90	0.90	-9	-0.09	815	114.10	367.43
100	1.00	-9	-0.09	840	117.60	378.70
120	1.20	-9	-0.09	855	119.70	385.46
140	1.40	-9	-0.09	890	124.60	401.24
160	1.60	-9	-0.09	915	128.10	412.51
180	1.80	-9	-0.09	935	130.90	421.53
200	2.00	-8	-0.08	950	133.00	428.29
250	2.50	-4	-0.04	975	136.50	439.56
300	3.00	-2	-0.02	985	137.90	444.07
350	3.50	-1	-0.01	995	139.30	448.58
400	4.00	-1	-0.01	995	139.30	448.58
450	4.50	-1	-0.01	995	139.30	448.58
500	5.00	-1	-0.01	995	139.30	448.58
550	5.50	-1	-0.01	995	139.30	448.58
600	6.00	-1	-0.01	995	139.30	448.58
650	6.50	-1	-0.01	995	139.30	448.58
700	7.00	-1	-0.01	995	139.30	448.58
750	7.50	-1	-0.01	995	139.30	448.58
800	8.00	-1	-0.01	995	139.30	448.58
850	8.50	-1	-0.01	995	139.30	448.58
900	9.00	-1	-0.01	995	139.30	448.58

Table A.23 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 7.54% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-4	-0.04	320	44.80	144.27
20	0.20	-6	-0.06	452	63.28	203.78
30	0.30	-7	-0.07	555	77.70	250.21
40	0.40	-8	-0.08	635	88.90	286.28
50	0.50	-9	-0.09	710	99.40	320.09
60	0.60	-9	-0.09	760	106.40	342.63
70	0.70	-9	-0.09	812	113.68	366.07
80	0.80	-9	-0.09	860	120.40	387.71
90	0.90	-10	-0.10	905	126.70	408.00
100	1.00	-10	-0.10	945	132.30	426.03
120	1.20	-10	-0.10	1005	140.70	453.08
140	1.40	-10	-0.10	1055	147.70	475.63
160	1.60	-10	-0.10	1095	153.30	493.66
180	1.80	-10	-0.10	1130	158.20	509.44
200	2.00	-10	-0.10	1155	161.70	520.71
250	2.50	-10	-0.10	1202	168.28	541.90
300	3.00	-10	-0.10	1230	172.20	554.52
350	3.50	-10	-0.10	1250	175.00	563.54
400	4.00	-10	-0.10	1255	175.70	565.79
450	4.50	-8	-0.08	1267	177.38	571.20
500	5.00	-7	-0.07	1268	177.52	571.65
550	5.50	-7	-0.07	1268	177.52	571.65
600	6.00	-7	-0.07	1268	177.52	571.65
650	6.50	-7	-0.07	1268	177.52	571.65
700	7.00	-7	-0.07	1268	177.52	571.65
750	7.50	-7	-0.07	1268	177.52	571.65
800	8.00	-7	-0.07	1268	177.52	571.65
850	8.50	-7	-0.07	1268	177.52	571.65
900	9.00	-7	-0.07	1268	177.52	571.65

Table A.24 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 7.20% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-2	-0.02	317	44.38	142.91
20	0.20	-4	-0.04	447	62.58	201.52
30	0.30	-5	-0.05	557	77.98	251.11
40	0.40	-6	-0.06	657	91.98	296.20
50	0.50	-7	-0.07	737	103.18	332.26
60	0.60	-7	-0.07	817	114.38	368.33
70	0.70	-8	-0.08	902	126.28	406.65
80	0.80	-8	-0.08	975	136.50	439.56
90	0.90	-8	-0.08	1042	145.88	469.77
100	1.00	-8	-0.08	1097	153.58	494.56
120	1.20	-8	-0.08	1177	164.78	530.63
140	1.40	-8	-0.08	1242	173.88	559.93
160	1.60	-8	-0.08	1297	181.58	584.73
180	1.80	-8	-0.08	1339	187.46	603.66
200	2.00	-8	-0.08	1377	192.78	620.79
250	2.50	-8	-0.08	1432	200.48	645.59
300	3.00	-6	-0.06	1457	203.98	656.86
350	3.50	-3	-0.03	1467	205.38	661.37
400	4.00	-1	-0.01	1472	206.08	663.62
450	4.50	-1	-0.01	1477	206.78	665.88
500	5.00	-1	-0.01	1479	207.06	666.78
550	5.50	-1	-0.01	1481	207.34	667.68
600	6.00	-1	-0.01	1482	207.48	668.13
650	6.50	-1	-0.01	1483	207.62	668.58
700	7.00	-1	-0.01	1485	207.90	669.48
750	7.50	-1	-0.01	1487	208.18	670.38
800	8.00	-1	-0.01	1487	208.18	670.38
850	8.50	-1	-0.01	1488	208.32	670.84
900	9.00	-1	-0.01	1489	208.46	671.29

Table A.25 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 10.28% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-4	-0.04	170	23.80	76.64
20	0.20	-5	-0.05	225	31.50	101.44
30	0.30	-7	-0.07	265	37.10	119.47
40	0.40	-8	-0.08	295	41.30	132.99
50	0.50	-9	-0.09	315	44.10	142.01
60	0.60	-10	-0.10	335	46.90	151.03
70	0.70	-11	-0.11	353	49.42	159.14
80	0.80	-11	-0.11	368	51.52	165.91
90	0.90	-11	-0.11	380	53.20	171.32
100	1.00	-12	-0.12	390	54.60	175.82
120	1.20	-12	-0.12	403	56.42	181.68
140	1.40	-12	-0.12	418	58.52	188.45
160	1.60	-12	-0.12	425	59.50	191.60
180	1.80	-12	-0.12	435	60.90	196.11
200	2.00	-8	-0.08	447	62.58	201.52
250	2.50	-7	-0.07	465	65.10	209.64
300	3.00	-6	-0.06	478	66.92	215.50
350	3.50	-6	-0.06	490	68.60	220.91
400	4.00	-6	-0.06	495	69.30	223.16
450	4.50	-6	-0.06	500	70.00	225.42
500	5.00	-6	-0.06	504	70.56	227.22
550	5.50	-6	-0.06	505	70.70	227.67
600	6.00	-6	-0.06	505	70.70	227.67
650	6.50	-6	-0.06	504	70.56	227.22
700	7.00	-6	-0.06	503	70.42	226.77
750	7.50	-6	-0.06	501	70.14	225.87
800	8.00	-6	-0.06	500	70.00	225.42

Table A.26 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 10.09% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	0	0.00	140	19.60	63.12
20	0.20	0	0.00	200	28.00	90.17
30	0.30	-1	-0.01	260	36.40	117.22
40	0.40	-2	-0.02	305	42.70	137.50
50	0.50	-3	-0.03	345	48.30	155.54
60	0.60	-4	-0.04	375	52.50	169.06
70	0.70	-5	-0.05	403	56.42	181.68
80	0.80	-5	-0.05	427	59.78	192.50
90	0.90	-6	-0.06	450	63.00	202.87
100	1.00	-7	-0.07	463	64.82	208.73
120	1.20	-7	-0.07	490	68.60	220.91
140	1.40	-8	-0.08	510	71.40	229.92
160	1.60	-8	-0.08	530	74.20	238.94
180	1.80	-9	-0.09	550	77.00	247.96
200	2.00	-10	-0.10	565	79.10	254.72
250	2.50	-10	-0.10	590	82.60	265.99
300	3.00	-12	-0.12	612	85.68	275.91
350	3.50	-13	-0.13	620	86.80	279.51
400	4.00	-14	-0.14	635	88.90	286.28
450	4.50	-15	-0.15	645	90.30	290.79
500	5.00	-15	-0.15	650	91.00	293.04
550	5.50	-15	-0.15	650	91.00	293.04
600	6.00	-15	-0.15	650	91.00	293.04
650	6.50	-15	-0.15	650	91.00	293.04
700	7.00	-15	-0.15	650	91.00	293.04
750	7.50	-15	-0.15	650	91.00	293.04
800	8.00	-15	-0.15	650	91.00	293.04

Table A.27 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 10.47% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-5	-0.05	185	25.90	83.40
20	0.20	-3	-0.03	265	37.10	119.47
30	0.30	-2	-0.02	320	44.80	144.27
40	0.40	0	0.00	370	51.80	166.81
50	0.50	-1	-0.01	417	58.38	188.00
60	0.60	-2	-0.02	470	65.80	211.89
70	0.70	-4	-0.04	500	70.00	225.42
80	0.80	-6	-0.06	530	74.20	238.94
90	0.90	-8	-0.08	550	77.00	247.96
100	1.00	-10	-0.10	580	81.20	261.48
120	1.20	-10	-0.10	615	86.10	277.26
140	1.40	-12	-0.12	650	91.00	293.04
160	1.60	-14	-0.14	678	94.92	305.66
180	1.80	-16	-0.16	703	98.42	316.93
200	2.00	-21	-0.21	725	101.50	326.85
250	2.50	-22	-0.22	765	107.10	344.89
300	3.00	-24	-0.24	797	111.58	359.31
350	3.50	-26	-0.26	805	112.70	362.92
400	4.00	-28	-0.28	810	113.40	365.17
450	4.50	-32	-0.32	815	114.10	367.43
500	5.00	-33	-0.33	825	115.50	371.93
550	5.50	-34	-0.34	829	116.06	373.74
600	6.00	-35	-0.35	833	116.62	375.54
650	6.50	-36	-0.36	836	117.04	376.89
700	7.00	-37	-0.37	839	117.46	378.25
750	7.50	-38	-0.38	840	117.60	378.70
800	8.00	-39	-0.39	840	117.60	378.70

Table A.28 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 10.14% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	0	0.00	140	19.60	63.12
20	0.20	-1	-0.01	230	32.20	103.69
30	0.30	-4	-0.04	320	44.80	144.27
40	0.40	-7	-0.07	395	55.30	178.08
50	0.50	-9	-0.09	455	63.70	205.13
60	0.60	-11	-0.11	510	71.40	229.92
70	0.70	-13	-0.13	553	77.42	249.31
80	0.80	-14	-0.14	592	82.88	266.89
90	0.90	-15	-0.15	620	86.80	279.51
100	1.00	-16	-0.16	643	90.02	289.88
120	1.20	-19	-0.19	675	94.50	304.31
140	1.40	-20	-0.20	700	98.00	315.58
160	1.60	-21	-0.21	753	105.42	339.48
180	1.80	-23	-0.23	795	111.30	358.41
200	2.00	-25	-0.25	830	116.20	374.19
250	2.50	-27	-0.27	895	125.30	403.49
300	3.00	-30	-0.30	930	130.20	419.27
350	3.50	-31	-0.31	960	134.40	432.80
400	4.00	-32	-0.32	995	139.30	448.58
450	4.50	-33	-0.33	1020	142.80	459.85
500	5.00	-33	-0.33	1037	145.18	467.51
550	5.50	-34	-0.34	1042	145.88	469.77
600	6.00	-34	-0.34	1046	146.44	471.57
650	6.50	-34	-0.34	1050	147.00	473.37
700	7.00	-34	-0.34	1055	147.70	475.63
750	7.50	-34	-0.34	1060	148.40	477.88
800	8.00	-34	-0.34	1064	148.96	479.68

Table A.29 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 11.99% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-9	-0.09	106	14.84	47.79
20	0.20	-11	-0.11	150	21.00	67.62
30	0.30	-12	-0.12	180	25.20	81.15
40	0.40	-13	-0.13	203	28.42	91.52
50	0.50	-15	-0.15	223	31.22	100.54
60	0.60	-16	-0.16	240	33.60	108.20
70	0.70	-17	-0.17	257	35.98	115.86
80	0.80	-18	-0.18	270	37.80	121.72
90	0.90	-19	-0.19	280	39.20	126.23
100	1.00	-20	-0.20	290	40.60	130.74
120	1.20	-21	-0.21	305	42.70	137.50
140	1.40	-22	-0.22	320	44.80	144.27
160	1.60	-22	-0.22	333	46.62	150.13
180	1.80	-22	-0.22	345	48.30	155.54
200	2.00	-22	-0.22	355	49.70	160.04
250	2.50	-22	-0.22	375	52.50	169.06
300	3.00	-22	-0.22	394	55.16	177.63
350	3.50	-21	-0.21	407	56.98	183.49
400	4.00	-22	-0.22	418	58.52	188.45
450	4.50	-23	-0.23	427	59.78	192.50
500	5.00	-24	-0.24	436	61.04	196.56
550	5.50	-25	-0.25	446	62.44	201.07
600	6.00	-26	-0.26	453	63.42	204.23
650	6.50	-27	-0.27	455	63.70	205.13
700	7.00	-28	-0.28	454	63.56	204.68
750	7.50	-29	-0.29	454	63.56	204.68
800	8.00	-30	-0.30	454	63.56	204.68

Table A.30 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 12.13% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-7	-0.07	290	40.60	130.74
20	0.20	-8	-0.08	320	44.80	144.27
30	0.30	-9	-0.09	345	48.30	155.54
40	0.40	-10	-0.10	366	51.24	165.00
50	0.50	-11	-0.11	385	53.90	173.57
60	0.60	-12	-0.12	401	56.14	180.78
70	0.70	-14	-0.14	413	57.82	186.19
80	0.80	-14	-0.14	423	59.22	190.70
90	0.90	-15	-0.15	433	60.62	195.21
100	1.00	-16	-0.16	444	62.16	200.17
120	1.20	-17	-0.17	458	64.12	206.48
140	1.40	-17	-0.17	473	66.22	213.24
160	1.60	-17	-0.17	486	68.04	219.10
180	1.80	-17	-0.17	495	69.30	223.16
200	2.00	-17	-0.17	501	70.14	225.87
250	2.50	-17	-0.17	522	73.08	235.33
300	3.00	-18	-0.18	550	77.00	247.96
350	3.50	-19	-0.19	565	79.10	254.72
400	4.00	-20	-0.20	575	80.50	259.23
450	4.50	-22	-0.22	585	81.90	263.74
500	5.00	-23	-0.23	592	82.88	266.89
550	5.50	-24	-0.24	600	84.00	270.50
600	6.00	-25	-0.25	610	85.40	275.01
650	6.50	-25	-0.25	615	86.10	277.26
700	7.00	-26	-0.26	625	87.50	281.77
750	7.50	-26	-0.26	635	88.90	286.28
800	8.00	-26	-0.26	640	89.60	288.53

Table A.31 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 12.35% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-9	-0.09	250	35.00	112.71
20	0.20	-12	-0.12	325	45.50	146.52
30	0.30	-13	-0.13	390	54.60	175.82
40	0.40	-15	-0.15	450	63.00	202.87
50	0.50	-16	-0.16	500	70.00	225.42
60	0.60	-17	-0.17	545	76.30	245.70
70	0.70	-18	-0.18	582	81.48	262.38
80	0.80	-18	-0.18	612	85.68	275.91
90	0.90	-19	-0.19	640	89.60	288.53
100	1.00	-19	-0.19	661	92.54	298.00
120	1.20	-20	-0.20	695	97.30	313.33
140	1.40	-20	-0.20	725	101.50	326.85
160	1.60	-21	-0.21	748	104.72	337.22
180	1.80	-21	-0.21	763	106.82	343.98
200	2.00	-21	-0.21	775	108.50	349.39
250	2.50	-22	-0.22	800	112.00	360.66
300	3.00	-23	-0.23	815	114.10	367.43
350	3.50	-24	-0.24	820	114.80	369.68
400	4.00	-25	-0.25	825	115.50	371.93
450	4.50	-26	-0.26	835	116.90	376.44
500	5.00	-27	-0.27	837	117.18	377.34
550	5.50	-28	-0.28	838	117.32	377.80
600	6.00	-29	-0.29	838	117.32	377.80
650	6.50	-30	-0.30	838	117.32	377.80
700	7.00	-31	-0.31	838	117.32	377.80
750	7.50	-32	-0.32	838	117.32	377.80
800	8.00	-33	-0.33	838	117.32	377.80

Table A.32 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 12.58% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-11	-0.11	200	28.00	90.17
20	0.20	-15	-0.15	295	41.30	132.99
30	0.30	-18	-0.18	365	51.10	164.55
40	0.40	-20	-0.20	425	59.50	191.60
50	0.50	-22	-0.22	493	69.02	222.26
60	0.60	-24	-0.24	550	77.00	247.96
70	0.70	-25	-0.25	600	84.00	270.50
80	0.80	-27	-0.27	640	89.60	288.53
90	0.90	-28	-0.28	680	95.20	306.56
100	1.00	-28	-0.28	710	99.40	320.09
120	1.20	-29	-0.29	765	107.10	344.89
140	1.40	-30	-0.30	805	112.70	362.92
160	1.60	-31	-0.31	840	117.60	378.70
180	1.80	-32	-0.32	870	121.80	392.22
200	2.00	-33	-0.33	890	124.60	401.24
250	2.50	-34	-0.34	920	128.80	414.76
300	3.00	-35	-0.35	945	132.30	426.03
350	3.50	-35	-0.35	954	133.56	430.09
400	4.00	-33	-0.33	964	134.96	434.60
450	4.50	-34	-0.34	985	137.90	444.07
500	5.00	-34	-0.34	990	138.60	446.32
550	5.50	-33	-0.33	990	138.60	446.32
600	6.00	-32	-0.32	995	139.30	448.58
650	6.50	-32	-0.32	1005	140.70	453.08
700	7.00	-32	-0.32	1010	141.40	455.34
750	7.50	-32	-0.32	1012	141.68	456.24
800	8.00	-32	-0.32	1014	141.96	457.14

Table A.33 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 14.33% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-1	-0.01	55	7.70	24.80
20	0.20	-4	-0.04	72	10.08	32.46
30	0.30	-7	-0.07	90	12.60	40.57
40	0.40	-8	-0.08	103	14.42	46.44
50	0.50	-10	-0.10	115	16.10	51.85
60	0.60	-11	-0.11	123	17.22	55.45
70	0.70	-13	-0.13	130	18.20	58.61
80	0.80	-14	-0.14	138	19.32	62.21
90	0.90	-15	-0.15	143	20.02	64.47
100	1.00	-17	-0.17	148	20.72	66.72
120	1.20	-18	-0.18	157	21.98	70.78
140	1.40	-20	-0.20	170	23.80	76.64
160	1.60	-22	-0.22	175	24.50	78.90
180	1.80	-23	-0.23	186	26.04	83.85
200	2.00	-24	-0.24	192	26.88	86.56
250	2.50	-26	-0.26	207	28.98	93.32
300	3.00	-29	-0.29	223	31.22	100.54
350	3.50	-30	-0.30	240	33.60	108.20
400	4.00	-32	-0.32	250	35.00	112.71
450	4.50	-34	-0.34	262	36.68	118.12
500	5.00	-34	-0.34	265	37.10	119.47
550	5.50	-35	-0.35	273	38.22	123.08
600	6.00	-35	-0.35	282	39.48	127.13
650	6.50	-35	-0.35	295	41.30	132.99
700	7.00	-36	-0.36	313	43.82	141.11
750	7.50	-36	-0.36	313	43.82	141.11
800	8.00	-36	-0.36	313	43.82	141.11

Table A.34 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 15.25% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	0	0.00	58	8.12	26.15
20	0.20	-2	-0.02	95	13.30	42.83
30	0.30	-5	-0.05	120	16.80	54.10
40	0.40	-8	-0.08	150	21.00	67.62
50	0.50	-10	-0.10	180	25.20	81.15
60	0.60	-12	-0.12	205	28.70	92.42
70	0.70	-14	-0.14	240	33.60	108.20
80	0.80	-15	-0.15	255	35.70	114.96
90	0.90	-17	-0.17	280	39.20	126.23
100	1.00	-18	-0.18	303	42.42	136.60
120	1.20	-20	-0.20	320	44.80	144.27
140	1.40	-22	-0.22	350	49.00	157.79
160	1.60	-24	-0.24	365	51.10	164.55
180	1.80	-24	-0.24	370	51.80	166.81
200	2.00	-25	-0.25	375	52.50	169.06
250	2.50	-28	-0.28	405	56.70	182.59
300	3.00	-29	-0.29	415	58.10	187.09
350	3.50	-31	-0.31	415	58.10	187.09
400	4.00	-32	-0.32	420	58.80	189.35
450	4.50	-33	-0.33	430	60.20	193.86
500	5.00	-35	-0.35	435	60.90	196.11
550	5.50	-35	-0.35	440	61.60	198.37
600	6.00	-35	-0.35	447	62.58	201.52
650	6.50	-36	-0.36	458	64.12	206.48
700	7.00	-37	-0.37	458	64.12	206.48
750	7.50	-39	-0.39	464	64.96	209.19
800	8.00	-40	-0.40	478	66.92	215.50

Table A.35 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 14.75% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-4	-0.04	65	9.10	29.30
20	0.20	-8	-0.08	100	14.00	45.08
30	0.30	-11	-0.11	135	18.90	60.86
40	0.40	-14	-0.14	155	21.70	69.88
50	0.50	-16	-0.16	190	26.60	85.66
60	0.60	-19	-0.19	220	30.80	99.18
70	0.70	-20	-0.20	250	35.00	112.71
80	0.80	-22	-0.22	270	37.80	121.72
90	0.90	-24	-0.24	290	40.60	130.74
100	1.00	-25	-0.25	310	43.40	139.76
120	1.20	-28	-0.28	348	48.72	156.89
140	1.40	-31	-0.31	375	52.50	169.06
160	1.60	-33	-0.33	403	56.42	181.68
180	1.80	-35	-0.35	430	60.20	193.86
200	2.00	-38	-0.38	457	63.98	206.03
250	2.50	-41	-0.41	517	72.38	233.08
300	3.00	-44	-0.44	580	81.20	261.48
350	3.50	-45	-0.45	615	86.10	277.26
400	4.00	-48	-0.48	643	90.02	289.88
450	4.50	-50	-0.50	665	93.10	299.80
500	5.00	-52	-0.52	690	96.60	311.07
550	5.50	-54	-0.54	690	96.60	311.07
600	6.00	-55	-0.55	690	96.60	311.07
650	6.50	-55	-0.55	690	96.60	311.07
700	7.00	-55	-0.55	690	96.60	311.07
750	7.50	-57	-0.57	690	96.60	311.07
800	8.00	-57	-0.57	690	96.60	311.07

Table A.36 Small-scale direct shear test with soil sample passing sieve no.4 at water content about 15.25% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div)	Vertical displacement (mm)	Load reading (div)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.10	-9	-0.09	80	11.20	36.07
20	0.20	-13	-0.13	125	17.50	56.35
30	0.30	-16	-0.16	165	23.10	74.39
40	0.40	-19	-0.19	210	29.40	94.67
50	0.50	-21	-0.21	250	35.00	112.71
60	0.60	-24	-0.24	282	39.48	127.13
70	0.70	-25	-0.25	310	43.40	139.76
80	0.80	-27	-0.27	340	47.60	153.28
90	0.90	-29	-0.29	360	50.40	162.30
100	1.00	-30	-0.30	383	53.62	172.67
120	1.20	-33	-0.33	430	60.20	193.86
140	1.40	-36	-0.36	465	65.10	209.64
160	1.60	-38	-0.38	495	69.30	223.16
180	1.80	-40	-0.40	523	73.22	235.78
200	2.00	-43	-0.43	553	77.42	249.31
250	2.50	-46	-0.46	600	84.00	270.50
300	3.00	-49	-0.49	635	88.90	286.28
350	3.50	-50	-0.50	670	93.80	302.06
400	4.00	-53	-0.53	696	97.44	313.78
450	4.50	-55	-0.55	715	100.10	322.34
500	5.00	-57	-0.57	740	103.60	333.61
550	5.50	-59	-0.59	758	106.12	341.73
600	6.00	-60	-0.60	785	109.90	353.90
650	6.50	-60	-0.60	792	110.88	357.06
700	7.00	-60	-0.60	805	112.70	362.92
750	7.50	-62	-0.62	825	115.50	371.93
800	8.00	-62	-0.62	830	116.20	374.19

Table A.37 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 2.51% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-3	-0.08	1000	454.00	159.29
20	0.51	-8	-0.20	1400	635.60	223.00
30	0.76	-13	-0.33	1800	817.20	286.71
40	1.02	-16	-0.41	2000	908.00	318.57
50	1.27	-17	-0.43	2100	953.40	334.50
60	1.52	-18	-0.46	2200	998.80	350.43
70	1.78	-19	-0.48	2300	1044.20	366.36
80	2.03	-19	-0.48	2400	1089.60	382.28
90	2.29	-20	-0.51	2400	1089.60	382.28
100	2.54	-21	-0.53	2400	1089.60	382.28
120	3.05	-21	-0.53	2400	1089.60	382.28
140	3.56	-21	-0.53	2400	1089.60	382.28
160	4.06	-21	-0.53	2400	1089.60	382.28
180	4.57	-21	-0.53	2400	1089.60	382.28
200	5.08	-21	-0.53	2400	1089.60	382.28
250	6.35	-22	-0.56	2400	1089.60	382.28
300	7.62	-22	-0.56	2400	1089.60	382.28
350	8.89	-23	-0.58	2200	998.80	350.43
400	10.16	-24	-0.61	2200	998.80	350.43
450	11.43	-25	-0.64	2200	998.80	350.43
500	12.70	-26	-0.66	2200	998.80	350.43
550	13.97	-27	-0.69	2200	998.80	350.43
600	15.24	-28	-0.71	2200	998.80	350.43

Table A.38 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 2.52% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-12	-0.30	2000	908.00	318.57
20	0.51	-16	-0.41	2300	1044.20	366.36
30	0.76	-20	-0.51	2600	1180.40	414.14
40	1.02	-22	-0.56	2900	1316.60	461.93
50	1.27	-25	-0.64	3100	1407.40	493.78
60	1.52	-29	-0.74	3200	1452.80	509.71
70	1.78	-31	-0.79	3400	1543.60	541.57
80	2.03	-32	-0.81	3500	1589.00	557.50
90	2.29	-34	-0.86	3600	1634.40	573.43
100	2.54	-34	-0.86	3600	1634.40	573.43
120	3.05	-34	-0.86	3700	1679.80	589.36
140	3.56	-36	-0.91	3700	1679.80	589.36
160	4.06	-36	-0.91	3800	1725.20	605.28
180	4.57	-36	-0.91	3800	1725.20	605.28
200	5.08	-36	-0.91	3800	1725.20	605.28
250	6.35	-36	-0.91	3800	1725.20	605.28
300	7.62	-36	-0.91	3800	1725.20	605.28
350	8.89	-36	-0.91	3800	1725.20	605.28
400	10.16	-36	-0.91	3800	1725.20	605.28
450	11.43	-36	-0.91	3700	1679.80	589.36
500	12.70	-36	-0.91	3700	1679.80	589.36
550	13.97	-36	-0.91	3700	1679.80	589.36
600	15.24	-36	-0.91	3700	1679.80	589.36

Table A.39 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 2.60% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-6	-0.15	2800	1271.20	446.00
20	0.51	-9	-0.23	2900	1316.60	461.93
30	0.76	-16	-0.41	3200	1452.80	509.71
40	1.02	-16	-0.41	3400	1543.60	541.57
50	1.27	-21	-0.53	3800	1725.20	605.28
60	1.52	-26	-0.66	3900	1770.60	621.21
70	1.78	-29	-0.74	4200	1906.80	669.00
80	2.03	-33	-0.84	4300	1952.20	684.93
90	2.29	-36	-0.91	4400	1997.60	700.86
100	2.54	-37	-0.94	4400	1997.60	700.86
120	3.05	-38	-0.97	4500	2043.00	716.78
140	3.56	-40	-1.02	4600	2088.40	732.71
160	4.06	-41	-1.04	4800	2179.20	764.57
180	4.57	-42	-1.07	4900	2224.60	780.50
200	5.08	-43	-1.09	5000	2270.00	796.43
250	6.35	-44	-1.12	5200	2360.80	828.28
300	7.62	-45	-1.14	5400	2451.60	860.14
350	8.89	-47	-1.19	5600	2542.40	892.00
400	10.16	-48	-1.22	5600	2542.40	892.00
450	11.43	-50	-1.27	5600	2542.40	892.00
500	12.70	-50	-1.27	5600	2542.40	892.00
550	13.97	-50	-1.27	5600	2542.40	892.00
600	15.24	-50	-1.27	5600	2542.40	892.00

Table A.40 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 2.54% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-1	-0.03	1400	635.60	223.00
20	0.51	-5	-0.13	2200	998.80	350.43
30	0.76	-10	-0.25	2600	1180.40	414.14
40	1.02	-14	-0.36	3000	1362.00	477.86
50	1.27	-19	-0.48	3400	1543.60	541.57
60	1.52	-23	-0.58	3600	1634.40	573.43
70	1.78	-26	-0.66	4000	1816.00	637.14
80	2.03	-29	-0.74	4200	1906.80	669.00
90	2.29	-32	-0.81	4400	1997.60	700.86
100	2.54	-35	-0.89	4600	2088.40	732.71
120	3.05	-37	-0.94	5000	2270.00	796.43
140	3.56	-39	-0.99	5400	2451.60	860.14
160	4.06	-42	-1.07	5800	2633.20	923.86
180	4.57	-44	-1.12	6000	2724.00	955.71
200	5.08	-47	-1.19	6200	2814.80	987.57
250	6.35	-50	-1.27	6400	2905.60	1019.43
300	7.62	-53	-1.35	6600	2996.40	1051.28
350	8.89	-55	-1.40	6800	3087.20	1083.14
400	10.16	-57	-1.45	7000	3178.00	1115.00
450	11.43	-60	-1.52	7000	3178.00	1115.00
500	12.70	-63	-1.60	7000	3178.00	1115.00
550	13.97	-65	-1.65	7000	3178.00	1115.00
600	15.24	-69	-1.75	7000	3178.00	1115.00

Table A.41 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 5.69% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-1	-0.03	1200	544.80	191.14
20	0.51	-2	-0.05	1300	590.20	207.07
30	0.76	-5	-0.13	1400	635.60	223.00
40	1.02	-7	-0.18	1500	681.00	238.93
50	1.27	-9	-0.23	1700	771.80	270.79
60	1.52	-10	-0.25	2000	908.00	318.57
70	1.78	-11	-0.28	2000	908.00	318.57
80	2.03	-12	-0.30	2000	908.00	318.57
90	2.29	-13	-0.33	2000	908.00	318.57
100	2.54	-13	-0.33	2000	908.00	318.57
120	3.05	-13	-0.33	2100	953.40	334.50
140	3.56	-14	-0.36	2200	998.80	350.43
160	4.06	-14	-0.36	2200	998.80	350.43
180	4.57	-14	-0.36	2200	998.80	350.43
200	5.08	-14	-0.36	2200	998.80	350.43
250	6.35	-14	-0.36	2200	998.80	350.43
300	7.62	-14	-0.36	2200	998.80	350.43
350	8.89	-14	-0.36	2200	998.80	350.43
400	10.16	-14	-0.36	2200	998.80	350.43
450	11.43	-14	-0.36	2200	998.80	350.43
500	12.70	-14	-0.36	2200	998.80	350.43
550	13.97	-14	-0.36	2200	998.80	350.43
600	15.24	-14	-0.36	2200	998.80	350.43

Table A.42 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 5.30% of normal stress is 703.01 kPa.

Horizontal reading (div)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-3	-0.08	3000	1362.00	477.86
20	0.51	-5	-0.13	3400	1543.60	541.57
30	0.76	-6	-0.15	3400	1543.60	541.57
40	1.02	-7	-0.18	3400	1543.60	541.57
50	1.27	-8	-0.20	3500	1589.00	557.50
60	1.52	-8	-0.20	3600	1634.40	573.43
70	1.78	-9	-0.23	3600	1634.40	573.43
80	2.03	-10	-0.25	3800	1725.20	605.28
90	2.29	-10	-0.25	4000	1816.00	637.14
100	2.54	-10	-0.25	4000	1816.00	637.14
120	3.05	-11	-0.28	4100	1861.40	653.07
140	3.56	-11	-0.28	4100	1861.40	653.07
160	4.06	-12	-0.30	4100	1861.40	653.07
180	4.57	-13	-0.33	4100	1861.40	653.07
200	5.08	-13	-0.33	4100	1861.40	653.07
250	6.35	-16	-0.41	4100	1861.40	653.07
300	7.62	-17	-0.43	4100	1861.40	653.07
350	8.89	-18	-0.46	4100	1861.40	653.07
400	10.16	-18	-0.46	4100	1861.40	653.07
450	11.43	-19	-0.48	4100	1861.40	653.07
500	12.70	-21	-0.53	4100	1861.40	653.07
550	13.97	-22	-0.56	4100	1861.40	653.07
600	15.24	-23	-0.58	4100	1861.40	653.07

Table A.43 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 5.53% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-2	-0.05	2400	1089.60	382.28
20	0.51	-4	-0.10	3000	1362.00	477.86
30	0.76	-5	-0.13	3500	1589.00	557.50
40	1.02	-6	-0.15	3700	1679.80	589.36
50	1.27	-7	-0.18	4000	1816.00	637.14
60	1.52	-9	-0.23	4200	1906.80	669.00
70	1.78	-10	-0.25	4300	1952.20	684.93
80	2.03	-11	-0.28	4400	1997.60	700.86
90	2.29	-13	-0.33	4500	2043.00	716.78
100	2.54	-14	-0.36	4600	2088.40	732.71
120	3.05	-16	-0.41	4700	2133.80	748.64
140	3.56	-18	-0.46	4800	2179.20	764.57
160	4.06	-20	-0.51	4900	2224.60	780.50
180	4.57	-22	-0.56	5000	2270.00	796.43
200	5.08	-24	-0.61	5100	2315.40	812.36
250	6.35	-31	-0.79	5200	2360.80	828.28
300	7.62	-35	-0.89	5300	2406.20	844.21
350	8.89	-37	-0.94	5400	2451.60	860.14
400	10.16	-39	-0.99	5500	2497.00	876.07
450	11.43	-40	-1.02	5500	2497.00	876.07
500	12.70	-41	-1.04	5500	2497.00	876.07
550	13.97	-43	-1.09	5500	2497.00	876.07
600	15.24	-45	-1.14	5500	2497.00	876.07

Table A.44 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 5.29% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-2	-0.05	3000	1362.00	477.86
20	0.51	-5	-0.13	3700	1679.80	589.36
30	0.76	-10	-0.25	4200	1906.80	669.00
40	1.02	-13	-0.33	4500	2043.00	716.78
50	1.27	-17	-0.43	4800	2179.20	764.57
60	1.52	-19	-0.48	4900	2224.60	780.50
70	1.78	-23	-0.58	5200	2360.80	828.28
80	2.03	-27	-0.69	5500	2497.00	876.07
90	2.29	-29	-0.74	5600	2542.40	892.00
100	2.54	-33	-0.84	5800	2633.20	923.86
120	3.05	-40	-1.02	6000	2724.00	955.71
140	3.56	-43	-1.09	6100	2769.40	971.64
160	4.06	-46	-1.17	6300	2860.20	1003.50
180	4.57	-48	-1.22	6400	2905.60	1019.43
200	5.08	-50	-1.27	6500	2951.00	1035.36
250	6.35	-51	-1.30	7000	3178.00	1115.00
300	7.62	-52	-1.32	7100	3223.40	1130.93
350	8.89	-53	-1.35	7100	3223.40	1130.93
400	10.16	-54	-1.37	7100	3223.40	1130.93
450	11.43	-55	-1.40	7000	3178.00	1115.00
500	12.70	-56	-1.42	7000	3178.00	1115.00
550	13.97	-57	-1.45	7000	3178.00	1115.00
600	15.24	-57	-1.45	7000	3178.00	1115.00

Table A.45 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 7.72% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-3	-0.08	1400	635.60	223.00
20	0.51	-5	-0.13	1600	726.40	254.86
30	0.76	-6	-0.15	1800	817.20	286.71
40	1.02	-8	-0.20	1900	862.60	302.64
50	1.27	-10	-0.25	2000	908.00	318.57
60	1.52	-12	-0.30	2000	908.00	318.57
70	1.78	-13	-0.33	2100	953.40	334.50
80	2.03	-16	-0.41	2200	998.80	350.43
90	2.29	-18	-0.46	2200	998.80	350.43
100	2.54	-19	-0.48	2300	1044.20	366.36
120	3.05	-20	-0.51	2300	1044.20	366.36
140	3.56	-22	-0.56	2300	1044.20	366.36
160	4.06	-24	-0.61	2300	1044.20	366.36
180	4.57	-25	-0.64	2300	1044.20	366.36
200	5.08	-25	-0.64	2300	1044.20	366.36
250	6.35	-26	-0.66	2300	1044.20	366.36
300	7.62	-26	-0.66	2300	1044.20	366.36
350	8.89	-26	-0.66	2300	1044.20	366.36
400	10.16	-26	-0.66	2300	1044.20	366.36
450	11.43	-26	-0.66	2300	1044.20	366.36
500	12.70	-26	-0.66	2300	1044.20	366.36
550	13.97	-26	-0.66	2300	1044.20	366.36
600	15.24	-26	-0.66	2300	1044.20	366.36

Table A.46 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 7.78% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-2	-0.05	2800	1271.20	446.00
20	0.51	-4	-0.10	3000	1362.00	477.86
30	0.76	-6	-0.15	3100	1407.40	493.78
40	1.02	-8	-0.20	3200	1452.80	509.71
50	1.27	-9	-0.23	3300	1498.20	525.64
60	1.52	-11	-0.28	3400	1543.60	541.57
70	1.78	-13	-0.33	3500	1589.00	557.50
80	2.03	-14	-0.36	3600	1634.40	573.43
90	2.29	-15	-0.38	3700	1679.80	589.36
100	2.54	-17	-0.43	3800	1725.20	605.28
120	3.05	-18	-0.46	3900	1770.60	621.21
140	3.56	-20	-0.51	4100	1861.40	653.07
160	4.06	-22	-0.56	4200	1906.80	669.00
180	4.57	-25	-0.64	4200	1906.80	669.00
200	5.08	-26	-0.66	4200	1906.80	669.00
250	6.35	-28	-0.71	4200	1906.80	669.00
300	7.62	-30	-0.76	4200	1906.80	669.00
350	8.89	-33	-0.84	4200	1906.80	669.00
400	10.16	-35	-0.89	4200	1906.80	669.00
450	11.43	-37	-0.94	4200	1906.80	669.00
500	12.70	-38	-0.97	4200	1906.80	669.00
550	13.97	-39	-0.99	4200	1906.80	669.00
600	15.24	-42	-1.07	4200	1906.80	669.00

Table A.47 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 7.43% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-3	-0.08	2500	1135.00	398.21
20	0.51	-6	-0.15	2800	1271.20	446.00
30	0.76	-8	-0.20	3000	1362.00	477.86
40	1.02	-12	-0.30	3300	1498.20	525.64
50	1.27	-16	-0.41	3600	1634.40	573.43
60	1.52	-18	-0.46	3800	1725.20	605.28
70	1.78	-20	-0.51	4000	1816.00	637.14
80	2.03	-23	-0.58	4200	1906.80	669.00
90	2.29	-26	-0.66	4300	1952.20	684.93
100	2.54	-28	-0.71	4400	1997.60	700.86
120	3.05	-30	-0.76	4500	2043.00	716.78
140	3.56	-33	-0.84	4600	2088.40	732.71
160	4.06	-35	-0.89	4700	2133.80	748.64
180	4.57	-38	-0.97	4800	2179.20	764.57
200	5.08	-40	-1.02	4900	2224.60	780.50
250	6.35	-42	-1.07	5000	2270.00	796.43
300	7.62	-44	-1.12	5100	2315.40	812.36
350	8.89	-47	-1.19	5200	2360.80	828.28
400	10.16	-49	-1.24	5200	2360.80	828.28
450	11.43	-51	-1.30	5200	2360.80	828.28
500	12.70	-52	-1.32	5200	2360.80	828.28
550	13.97	-54	-1.37	5100	2315.40	812.36
600	15.24	-56	-1.42	5100	2315.40	812.36

Table A.48 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 7.69% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-17	-0.43	2800	1271.20	446.00
20	0.51	-21	-0.53	3300	1498.20	525.64
30	0.76	-24	-0.61	3800	1725.20	605.28
40	1.02	-27	-0.69	4300	1952.20	684.93
50	1.27	-31	-0.79	4800	2179.20	764.57
60	1.52	-34	-0.86	4900	2224.60	780.50
70	1.78	-36	-0.91	5100	2315.40	812.36
80	2.03	-38	-0.97	5200	2360.80	828.28
90	2.29	-41	-1.04	5300	2406.20	844.21
100	2.54	-44	-1.12	5400	2451.60	860.14
120	3.05	-45	-1.14	5500	2497.00	876.07
140	3.56	-47	-1.19	5600	2542.40	892.00
160	4.06	-48	-1.22	5700	2587.80	907.93
180	4.57	-50	-1.27	5800	2633.20	923.86
200	5.08	-52	-1.32	6000	2724.00	955.71
250	6.35	-54	-1.37	6200	2814.80	987.57
300	7.62	-55	-1.40	6400	2905.60	1019.43
350	8.89	-57	-1.45	6800	3087.20	1083.14
400	10.16	-59	-1.50	6900	3132.60	1099.07
450	11.43	-61	-1.55	6900	3132.60	1099.07
500	12.70	-63	-1.60	6900	3132.60	1099.07
550	13.97	-65	-1.65	6900	3132.60	1099.07
600	15.24	-67	-1.70	6900	3132.60	1099.07

Table A.49 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 10.56% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-7	-0.18	1000	454.00	159.29
20	0.51	-9	-0.23	1200	544.80	191.14
30	0.76	-10	-0.25	1400	635.60	223.00
40	1.02	-12	-0.30	1500	681.00	238.93
50	1.27	-14	-0.36	1600	726.40	254.86
60	1.52	-16	-0.41	1700	771.80	270.79
70	1.78	-17	-0.43	1800	817.20	286.71
80	2.03	-20	-0.51	1900	862.60	302.64
90	2.29	-22	-0.56	2000	908.00	318.57
100	2.54	-23	-0.58	2200	998.80	350.43
120	3.05	-24	-0.61	2200	998.80	350.43
140	3.56	-26	-0.66	2200	998.80	350.43
160	4.06	-28	-0.71	2200	998.80	350.43
180	4.57	-29	-0.74	2200	998.80	350.43
200	5.08	-29	-0.74	2200	998.80	350.43
250	6.35	-30	-0.76	2000	908.00	318.57
300	7.62	-30	-0.76	2000	908.00	318.57
350	8.89	-30	-0.76	2000	908.00	318.57
400	10.16	-30	-0.76	2000	908.00	318.57
450	11.43	-30	-0.76	2000	908.00	318.57
500	12.70	-30	-0.76	2000	908.00	318.57
550	13.97	-30	-0.76	2000	908.00	318.57
600	15.24	-30	-0.76	2000	908.00	318.57

Table A.50 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 9.85% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-10	-0.25	1200	544.80	191.14
20	0.51	-12	-0.30	1400	635.60	223.00
30	0.76	-15	-0.38	1600	726.40	254.86
40	1.02	-18	-0.46	1800	817.20	286.71
50	1.27	-21	-0.53	2000	908.00	318.57
60	1.52	-23	-0.58	2200	998.80	350.43
70	1.78	-24	-0.61	2400	1089.60	382.28
80	2.03	-25	-0.64	2600	1180.40	414.14
90	2.29	-27	-0.69	2700	1225.80	430.07
100	2.54	-29	-0.74	2800	1271.20	446.00
120	3.05	-31	-0.79	2900	1316.60	461.93
140	3.56	-32	-0.81	3000	1362.00	477.86
160	4.06	-34	-0.86	3100	1407.40	493.78
180	4.57	-36	-0.91	3200	1452.80	509.71
200	5.08	-38	-0.97	3200	1452.80	509.71
250	6.35	-41	-1.04	3200	1452.80	509.71
300	7.62	-43	-1.09	3200	1452.80	509.71
350	8.89	-45	-1.14	3200	1452.80	509.71
400	10.16	-47	-1.19	3200	1452.80	509.71
450	11.43	-49	-1.24	3200	1452.80	509.71
500	12.70	-51	-1.30	3200	1452.80	509.71
550	13.97	-53	-1.35	3100	1407.40	493.78
600	15.24	-55	-1.40	3100	1407.40	493.78

Table A.51 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 10.35% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-11	-0.28	1800	817.20	286.71
20	0.51	-16	-0.41	2000	908.00	318.57
30	0.76	-20	-0.51	2200	998.80	350.43
40	1.02	-24	-0.61	2400	1089.60	382.28
50	1.27	-28	-0.71	2600	1180.40	414.14
60	1.52	-32	-0.81	2800	1271.20	446.00
70	1.78	-34	-0.86	3000	1362.00	477.86
80	2.03	-36	-0.91	3200	1452.80	509.71
90	2.29	-39	-0.99	3400	1543.60	541.57
100	2.54	-42	-1.07	3600	1634.40	573.43
120	3.05	-44	-1.12	3800	1725.20	605.28
140	3.56	-46	-1.17	3900	1770.60	621.21
160	4.06	-47	-1.19	4000	1816.00	637.14
180	4.57	-49	-1.24	4100	1861.40	653.07
200	5.08	-50	-1.27	4200	1906.80	669.00
250	6.35	-52	-1.32	4300	1952.20	684.93
300	7.62	-53	-1.35	4400	1997.60	700.86
350	8.89	-54	-1.37	4500	2043.00	716.78
400	10.16	-55	-1.40	4500	2043.00	716.78
450	11.43	-57	-1.45	4500	2043.00	716.78
500	12.70	-58	-1.47	4500	2043.00	716.78
550	13.97	-59	-1.50	4500	2043.00	716.78
600	15.24	-61	-1.55	4500	2043.00	716.78

Table A.52 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 10.79% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-8	-0.20	2200	998.80	350.43
20	0.51	-12	-0.30	2500	1135.00	398.21
30	0.76	-15	-0.38	2700	1225.80	430.07
40	1.02	-18	-0.46	2900	1316.60	461.93
50	1.27	-23	-0.58	3200	1452.80	509.71
60	1.52	-26	-0.66	3400	1543.60	541.57
70	1.78	-29	-0.74	3600	1634.40	573.43
80	2.03	-32	-0.81	3800	1725.20	605.28
90	2.29	-35	-0.89	4000	1816.00	637.14
100	2.54	-38	-0.97	4200	1906.80	669.00
120	3.05	-42	-1.07	4400	1997.60	700.86
140	3.56	-44	-1.12	4600	2088.40	732.71
160	4.06	-47	-1.19	4800	2179.20	764.57
180	4.57	-51	-1.30	4900	2224.60	780.50
200	5.08	-54	-1.37	5000	2270.00	796.43
250	6.35	-58	-1.47	5100	2315.40	812.36
300	7.62	-62	-1.57	5200	2360.80	828.28
350	8.89	-68	-1.73	5300	2406.20	844.21
400	10.16	-64	-1.63	5400	2451.60	860.14
450	11.43	-68	-1.73	5500	2497.00	876.07
500	12.70	-70	-1.78	5600	2542.40	892.00
550	13.97	-72	-1.83	5600	2542.40	892.00
600	15.24	-75	-1.91	5600	2542.40	892.00

Table A.53 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 12.40% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-8	-0.20	800	363.20	127.43
20	0.51	-10	-0.25	1000	454.00	159.29
30	0.76	-12	-0.30	1000	454.00	159.29
40	1.02	-14	-0.36	1000	454.00	159.29
50	1.27	-16	-0.41	1100	499.40	175.21
60	1.52	-18	-0.46	1100	499.40	175.21
70	1.78	-20	-0.51	1100	499.40	175.21
80	2.03	-22	-0.56	1200	544.80	191.14
90	2.29	-24	-0.61	1200	544.80	191.14
100	2.54	-26	-0.66	1300	590.20	207.07
120	3.05	-28	-0.71	1300	590.20	207.07
140	3.56	-30	-0.76	1400	635.60	223.00
160	4.06	-32	-0.81	1500	681.00	238.93
180	4.57	-34	-0.86	1600	726.40	254.86
200	5.08	-36	-0.91	1700	771.80	270.79
250	6.35	-38	-0.97	1800	817.20	286.71
300	7.62	-40	-1.02	1800	817.20	286.71
350	8.89	-41	-1.04	1800	817.20	286.71
400	10.16	-42	-1.07	1800	817.20	286.71
450	11.43	-44	-1.12	1800	817.20	286.71
500	12.70	-46	-1.17	1800	817.20	286.71
550	13.97	-48	-1.22	1800	817.20	286.71
600	15.24	-50	-1.27	1800	817.20	286.71

Table A.54 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 12.51% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-5	-0.13	1000	454.00	159.29
20	0.51	-8	-0.20	1200	544.80	191.14
30	0.76	-10	-0.25	1300	590.20	207.07
40	1.02	-13	-0.33	1400	635.60	223.00
50	1.27	-15	-0.38	1500	681.00	238.93
60	1.52	-16	-0.41	1600	726.40	254.86
70	1.78	-19	-0.48	1600	726.40	254.86
80	2.03	-21	-0.53	1700	771.80	270.79
90	2.29	-23	-0.58	1800	817.20	286.71
100	2.54	-25	-0.64	1900	862.60	302.64
120	3.05	-28	-0.71	2000	908.00	318.57
140	3.56	-30	-0.76	2100	953.40	334.50
160	4.06	-32	-0.81	2200	998.80	350.43
180	4.57	-33	-0.84	2300	1044.20	366.36
200	5.08	-34	-0.86	2400	1089.60	382.28
250	6.35	-37	-0.94	2500	1135.00	398.21
300	7.62	-39	-0.99	2500	1135.00	398.21
350	8.89	-40	-1.02	2500	1135.00	398.21
400	10.16	-42	-1.07	2500	1135.00	398.21
450	11.43	-44	-1.12	2500	1135.00	398.21
500	12.70	-46	-1.17	2500	1135.00	398.21
550	13.97	-48	-1.22	2500	1135.00	398.21
600	15.24	-50	-1.27	2500	1135.00	398.21

Table A.55 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 12.87% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-8	-0.20	1800	817.20	286.71
20	0.51	-14	-0.36	2000	908.00	318.57
30	0.76	-17	-0.43	2200	998.80	350.43
40	1.02	-22	-0.56	2400	1089.60	382.28
50	1.27	-27	-0.69	2600	1180.40	414.14
60	1.52	-32	-0.81	2700	1225.80	430.07
70	1.78	-34	-0.86	2800	1271.20	446.00
80	2.03	-36	-0.91	2900	1316.60	461.93
90	2.29	-37	-0.94	3000	1362.00	477.86
100	2.54	-38	-0.97	3100	1407.40	493.78
120	3.05	-39	-0.99	3200	1452.80	509.71
140	3.56	-40	-1.02	3200	1452.80	509.71
160	4.06	-41	-1.04	3200	1452.80	509.71
180	4.57	-41	-1.04	3300	1498.20	525.64
200	5.08	-42	-1.07	3300	1498.20	525.64
250	6.35	-43	-1.09	3300	1498.20	525.64
300	7.62	-44	-1.12	3300	1498.20	525.64
350	8.89	-45	-1.14	3300	1498.20	525.64
400	10.16	-46	-1.17	3300	1498.20	525.64
450	11.43	-46	-1.17	3300	1498.20	525.64
500	12.70	-46	-1.17	3300	1498.20	525.64
550	13.97	-47	-1.19	3300	1498.20	525.64
600	15.24	-47	-1.19	3300	1498.20	525.64

Table A.56 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 12.70% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-15	-0.38	2200	998.80	350.43
20	0.51	-19	-0.48	2400	1089.60	382.28
30	0.76	-21	-0.53	2600	1180.40	414.14
40	1.02	-25	-0.64	2800	1271.20	446.00
50	1.27	-27	-0.69	3000	1362.00	477.86
60	1.52	-30	-0.76	3100	1407.40	493.78
70	1.78	-32	-0.81	3200	1452.80	509.71
80	2.03	-33	-0.84	3300	1498.20	525.64
90	2.29	-34	-0.86	3400	1543.60	541.57
100	2.54	-35	-0.89	3500	1589.00	557.50
120	3.05	-37	-0.94	3600	1634.40	573.43
140	3.56	-40	-1.02	3700	1679.80	589.36
160	4.06	-41	-1.04	3800	1725.20	605.28
180	4.57	-42	-1.07	3900	1770.60	621.21
200	5.08	-43	-1.09	4000	1816.00	637.14
250	6.35	-44	-1.12	4100	1861.40	653.07
300	7.62	-45	-1.14	4200	1906.80	669.00
350	8.89	-46	-1.17	4300	1952.20	684.93
400	10.16	-47	-1.19	4400	1997.60	700.86
450	11.43	-48	-1.22	4400	1997.60	700.86
500	12.70	-49	-1.24	4400	1997.60	700.86
550	13.97	-50	-1.27	4400	1997.60	700.86
600	15.24	-51	-1.30	4400	1997.60	700.86

Table A.57 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 14.93% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-2	-0.05	800	363.20	127.43
20	0.51	-3	-0.08	800	363.20	127.43
30	0.76	-4	-0.10	900	408.60	143.36
40	1.02	-5	-0.13	900	408.60	143.36
50	1.27	-7	-0.18	900	408.60	143.36
60	1.52	-8	-0.20	900	408.60	143.36
70	1.78	-9	-0.23	1000	454.00	159.29
80	2.03	-10	-0.25	1100	499.40	175.21
90	2.29	-12	-0.30	1200	544.80	191.14
100	2.54	-13	-0.33	1200	544.80	191.14
120	3.05	-14	-0.36	1300	590.20	207.07
140	3.56	-15	-0.38	1300	590.20	207.07
160	4.06	-16	-0.41	1300	590.20	207.07
180	4.57	-17	-0.43	1300	590.20	207.07
200	5.08	-18	-0.46	1300	590.20	207.07
250	6.35	-21	-0.53	1300	590.20	207.07
300	7.62	-22	-0.56	1300	590.20	207.07
350	8.89	-23	-0.58	1300	590.20	207.07
400	10.16	-23	-0.58	1300	590.20	207.07
450	11.43	-24	-0.61	1200	544.80	191.14
500	12.70	-25	-0.64	1200	544.80	191.14
550	13.97	-26	-0.66	1200	544.80	191.14
600	15.24	-27	-0.69	1200	544.80	191.14

Table A.58 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 15.15% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-4	-0.10	700	317.80	111.50
20	0.51	-10	-0.25	800	363.20	127.43
30	0.76	-12	-0.30	1000	454.00	159.29
40	1.02	-15	-0.38	1100	499.40	175.21
50	1.27	-19	-0.48	1200	544.80	191.14
60	1.52	-21	-0.53	1300	590.20	207.07
70	1.78	-24	-0.61	1400	635.60	223.00
80	2.03	-25	-0.64	1500	681.00	238.93
90	2.29	-26	-0.66	1600	726.40	254.86
100	2.54	-29	-0.74	1700	771.80	270.79
120	3.05	-32	-0.81	1800	817.20	286.71
140	3.56	-34	-0.86	1900	862.60	302.64
160	4.06	-35	-0.89	2000	908.00	318.57
180	4.57	-36	-0.91	2000	908.00	318.57
200	5.08	-37	-0.94	2000	908.00	318.57
250	6.35	-39	-0.99	2000	908.00	318.57
300	7.62	-41	-1.04	2000	908.00	318.57
350	8.89	-43	-1.09	2000	908.00	318.57
400	10.16	-44	-1.12	2000	908.00	318.57
450	11.43	-47	-1.19	2000	908.00	318.57
500	12.70	-48	-1.22	2000	908.00	318.57
550	13.97	-49	-1.24	2000	908.00	318.57
600	15.24	-50	-1.27	2000	908.00	318.57

Table A.59 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 15.61% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-6	-0.15	1100	499.40	175.21
20	0.51	-8	-0.20	1200	544.80	191.14
30	0.76	-10	-0.25	1400	635.60	223.00
40	1.02	-13	-0.33	1500	681.00	238.93
50	1.27	-16	-0.41	1600	726.40	254.86
60	1.52	-19	-0.48	1700	771.80	270.79
70	1.78	-22	-0.56	1800	817.20	286.71
80	2.03	-25	-0.64	1900	862.60	302.64
90	2.29	-27	-0.69	2000	908.00	318.57
100	2.54	-29	-0.74	2000	908.00	318.57
120	3.05	-33	-0.84	2100	953.40	334.50
140	3.56	-36	-0.91	2100	953.40	334.50
160	4.06	-38	-0.97	2200	998.80	350.43
180	4.57	-39	-0.99	2200	998.80	350.43
200	5.08	-41	-1.04	2300	1044.20	366.36
250	6.35	-43	-1.09	2400	1089.60	382.28
300	7.62	-47	-1.19	2600	1180.40	414.14
350	8.89	-51	-1.30	2800	1271.20	446.00
400	10.16	-54	-1.37	2800	1271.20	446.00
450	11.43	-57	-1.45	2800	1271.20	446.00
500	12.70	-59	-1.50	2800	1271.20	446.00
550	13.97	-60	-1.52	2800	1271.20	446.00
600	15.24	-62	-1.57	2800	1271.20	446.00

Table A.60 Large-scale direct shear test with soil sample passing sieve no.4 at water content about 15.87% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-18	-0.46	1400	635.60	223.00
20	0.51	-22	-0.56	1600	726.40	254.86
30	0.76	-24	-0.61	1800	817.20	286.71
40	1.02	-26	-0.66	1900	862.60	302.64
50	1.27	-27	-0.69	2000	908.00	318.57
60	1.52	-28	-0.71	2100	953.40	334.50
70	1.78	-29	-0.74	2200	998.80	350.43
80	2.03	-30	-0.76	2300	1044.20	366.36
90	2.29	-32	-0.81	2400	1089.60	382.28
100	2.54	-33	-0.84	2500	1135.00	398.21
120	3.05	-35	-0.89	2600	1180.40	414.14
140	3.56	-36	-0.91	2700	1225.80	430.07
160	4.06	-37	-0.94	2800	1271.20	446.00
180	4.57	-39	-0.99	2900	1316.60	461.93
200	5.08	-41	-1.04	3000	1362.00	477.86
250	6.35	-43	-1.09	3200	1452.80	509.71
300	7.62	-44	-1.12	3400	1543.60	541.57
350	8.89	-46	-1.17	3400	1543.60	541.57
400	10.16	-49	-1.24	3400	1543.60	541.57
450	11.43	-51	-1.30	3400	1543.60	541.57
500	12.70	-53	-1.35	3400	1543.60	541.57
550	13.97	-54	-1.37	3400	1543.60	541.57
600	15.24	-56	-1.42	3400	1543.60	541.57

Table A.61 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 2.27% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-1	-0.03	1400	635.60	220.56
20	0.51	-1	-0.03	1800	817.20	283.58
30	0.76	-1	-0.03	2000	908.00	315.09
40	1.02	-1	-0.03	2200	998.80	346.60
50	1.27	-1	-0.03	2300	1044.20	362.35
60	1.52	-1	-0.03	2400	1089.60	378.11
70	1.78	-1	-0.03	2400	1089.60	378.11
80	2.03	-2	-0.05	2500	1135.00	393.86
90	2.29	-3	-0.08	2500	1135.00	393.86
100	2.54	-4	-0.10	2600	1180.40	409.61
120	3.05	-7	-0.18	2600	1180.40	409.61
140	3.56	-10	-0.25	2800	1271.20	441.12
160	4.06	-13	-0.33	2800	1271.20	441.12
180	4.57	-17	-0.43	2800	1271.20	441.12
200	5.08	-20	-0.51	2800	1271.20	441.12
250	6.35	-22	-0.56	2800	1271.20	441.12
300	7.62	-24	-0.61	2800	1271.20	441.12
350	8.89	-26	-0.66	2800	1271.20	441.12
400	10.16	-28	-0.71	2600	1180.40	409.61
450	11.43	-30	-0.76	2600	1180.40	409.61
500	12.70	-31	-0.79	2600	1180.40	409.61
550	13.97	-32	-0.81	2600	1180.40	409.61
600	15.24	-33	-0.84	2600	1180.40	409.61

Table A.62 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 2.28% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-11	-0.28	1600	726.40	252.07
20	0.51	-13	-0.33	2400	1089.60	378.11
30	0.76	-14	-0.36	2800	1271.20	441.12
40	1.02	-15	-0.38	3000	1362.00	472.63
50	1.27	-15	-0.38	3200	1452.80	504.14
60	1.52	-15	-0.38	3400	1543.60	535.65
70	1.78	-16	-0.41	3600	1634.40	567.16
80	2.03	-18	-0.46	3800	1725.20	598.67
90	2.29	-20	-0.51	4000	1816.00	630.18
100	2.54	-21	-0.53	4200	1906.80	661.68
120	3.05	-23	-0.58	4400	1997.60	693.19
140	3.56	-25	-0.64	4600	2088.40	724.70
160	4.06	-27	-0.69	4800	2179.20	756.21
180	4.57	-29	-0.74	4800	2179.20	756.21
200	5.08	-30	-0.76	4800	2179.20	756.21
250	6.35	-32	-0.81	4800	2179.20	756.21
300	7.62	-34	-0.86	4800	2179.20	756.21
350	8.89	-36	-0.91	4800	2179.20	756.21
400	10.16	-38	-0.97	4800	2179.20	756.21
450	11.43	-40	-1.02	4800	2179.20	756.21
500	12.70	-41	-1.04	4600	2088.40	724.70
550	13.97	-43	-1.09	4600	2088.40	724.70
600	15.24	-45	-1.14	4600	2088.40	724.70

Table A.63 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 2.89% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-4	-0.10	1400	635.60	220.56
20	0.51	-10	-0.25	2200	998.80	346.60
30	0.76	-13	-0.33	3000	1362.00	472.63
40	1.02	-15	-0.38	3400	1543.60	535.65
50	1.27	-18	-0.46	3800	1725.20	598.67
60	1.52	-20	-0.51	4000	1816.00	630.18
70	1.78	-22	-0.56	4400	1997.60	693.19
80	2.03	-23	-0.58	4600	2088.40	724.70
90	2.29	-24	-0.61	4800	2179.20	756.21
100	2.54	-25	-0.64	5000	2270.00	787.72
120	3.05	-29	-0.74	5600	2542.40	882.25
140	3.56	-30	-0.76	6000	2724.00	945.26
160	4.06	-30	-0.76	6000	2724.00	945.26
180	4.57	-34	-0.86	6400	2905.60	1008.28
200	5.08	-36	-0.91	6600	2996.40	1039.79
250	6.35	-40	-1.02	6600	2996.40	1039.79
300	7.62	-46	-1.17	6600	2996.40	1039.79
350	8.89	-51	-1.30	6400	2905.60	1008.28
400	10.16	-53	-1.35	6200	2814.80	976.77
450	11.43	-54	-1.37	6200	2814.80	976.77
500	12.70	-55	-1.40	6000	2724.00	945.26
550	13.97	-56	-1.42	5800	2633.20	913.75
600	15.24	-58	-1.47	5800	2633.20	913.75

Table A.64 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 2.54% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-1	-0.03	2000	908.00	315.09
20	0.51	-3	-0.08	3000	1362.00	472.63
30	0.76	-5	-0.13	3500	1589.00	551.40
40	1.02	-10	-0.25	4000	1816.00	630.18
50	1.27	-15	-0.38	4400	1997.60	693.19
60	1.52	-19	-0.48	4800	2179.20	756.21
70	1.78	-22	-0.56	5200	2360.80	819.23
80	2.03	-26	-0.66	5600	2542.40	882.25
90	2.29	-29	-0.74	6600	2996.40	1039.79
100	2.54	-33	-0.84	7000	3178.00	1102.81
120	3.05	-37	-0.94	7200	3268.80	1134.32
140	3.56	-41	-1.04	7400	3359.60	1165.83
160	4.06	-44	-1.12	7500	3405.00	1181.58
180	4.57	-47	-1.19	7600	3450.40	1197.33
200	5.08	-50	-1.27	7700	3495.80	1213.09
250	6.35	-54	-1.37	7800	3541.20	1228.84
300	7.62	-57	-1.45	7800	3541.20	1228.84
350	8.89	-60	-1.52	7800	3541.20	1228.84
400	10.16	-62	-1.57	7600	3450.40	1197.33
450	11.43	-64	-1.63	7600	3450.40	1197.33
500	12.70	-66	-1.68	7600	3450.40	1197.33
550	13.97	-68	-1.73	7600	3450.40	1197.33
600	15.24	-71	-1.80	7600	3450.40	1197.33

Table A.65 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 4.92% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-5	-0.13	1600	726.40	252.07
20	0.51	-8	-0.20	2200	998.80	346.60
30	0.76	-11	-0.28	2600	1180.40	409.61
40	1.02	-14	-0.36	2600	1180.40	409.61
50	1.27	-16	-0.41	2800	1271.20	441.12
60	1.52	-18	-0.46	2800	1271.20	441.12
70	1.78	-21	-0.53	2800	1271.20	441.12
80	2.03	-23	-0.58	2800	1271.20	441.12
90	2.29	-24	-0.61	2800	1271.20	441.12
100	2.54	-25	-0.64	3000	1362.00	472.63
120	3.05	-27	-0.69	3000	1362.00	472.63
140	3.56	-28	-0.71	3000	1362.00	472.63
160	4.06	-30	-0.76	3000	1362.00	472.63
180	4.57	-31	-0.79	3000	1362.00	472.63
200	5.08	-33	-0.84	2800	1271.20	441.12
250	6.35	-35	-0.89	2800	1271.20	441.12
300	7.62	-36	-0.91	2600	1180.40	409.61
350	8.89	-38	-0.97	2600	1180.40	409.61
400	10.16	-39	-0.99	2600	1180.40	409.61
450	11.43	-40	-1.02	2600	1180.40	409.61
500	12.70	-42	-1.07	2600	1180.40	409.61
550	13.97	-43	-1.09	2600	1180.40	409.61
600	15.24	-44	-1.12	2600	1180.40	409.61

Table A.66 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 4.96% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-6	-0.15	2000	908.00	315.09
20	0.51	-8	-0.20	2600	1180.40	409.61
30	0.76	-11	-0.28	3600	1634.40	567.16
40	1.02	-14	-0.36	3800	1725.20	598.67
50	1.27	-17	-0.43	4200	1906.80	661.68
60	1.52	-21	-0.53	4400	1997.60	693.19
70	1.78	-23	-0.58	4600	2088.40	724.70
80	2.03	-26	-0.66	4600	2088.40	724.70
90	2.29	-28	-0.71	4600	2088.40	724.70
100	2.54	-31	-0.79	4800	2179.20	756.21
120	3.05	-33	-0.84	4800	2179.20	756.21
140	3.56	-35	-0.89	4800	2179.20	756.21
160	4.06	-37	-0.94	5000	2270.00	787.72
180	4.57	-40	-1.02	5000	2270.00	787.72
200	5.08	-42	-1.07	5000	2270.00	787.72
250	6.35	-43	-1.09	5000	2270.00	787.72
300	7.62	-45	-1.14	4800	2179.20	756.21
350	8.89	-46	-1.17	4800	2179.20	756.21
400	10.16	-48	-1.22	4600	2088.40	724.70
450	11.43	-49	-1.24	4600	2088.40	724.70
500	12.70	-51	-1.30	4200	1906.80	661.68
550	13.97	-54	-1.37	4200	1906.80	661.68
600	15.24	-56	-1.42	4200	1906.80	661.68

Table A.67 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 5.03% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-7	-0.18	2000	908.00	315.09
20	0.51	-11	-0.28	2800	1271.20	441.12
30	0.76	-15	-0.38	3600	1634.40	567.16
40	1.02	-18	-0.46	4000	1816.00	630.18
50	1.27	-22	-0.56	4600	2088.40	724.70
60	1.52	-23	-0.58	5000	2270.00	787.72
70	1.78	-25	-0.64	5000	2270.00	787.72
80	2.03	-26	-0.66	5200	2360.80	819.23
90	2.29	-30	-0.76	5200	2360.80	819.23
100	2.54	-33	-0.84	5200	2360.80	819.23
120	3.05	-35	-0.89	5400	2451.60	850.74
140	3.56	-38	-0.97	5400	2451.60	850.74
160	4.06	-41	-1.04	5600	2542.40	882.25
180	4.57	-44	-1.12	5800	2633.20	913.75
200	5.08	-48	-1.22	6000	2724.00	945.26
250	6.35	-50	-1.27	6200	2814.80	976.77
300	7.62	-52	-1.32	6200	2814.80	976.77
350	8.89	-54	-1.37	6200	2814.80	976.77
400	10.16	-56	-1.42	6000	2724.00	945.26
450	11.43	-58	-1.47	6000	2724.00	945.26
500	12.70	-59	-1.50	6000	2724.00	945.26
550	13.97	-60	-1.52	5800	2633.20	913.75
600	15.24	-61	-1.55	5800	2633.20	913.75

Table A.68 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 5.09% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-11	-0.28	2400	1089.60	378.11
20	0.51	-16	-0.41	3400	1543.60	535.65
30	0.76	-19	-0.48	4000	1816.00	630.18
40	1.02	-24	-0.61	4400	1997.60	693.19
50	1.27	-27	-0.69	5000	2270.00	787.72
60	1.52	-30	-0.76	5600	2542.40	882.25
70	1.78	-33	-0.84	6000	2724.00	945.26
80	2.03	-37	-0.94	6200	2814.80	976.77
90	2.29	-38	-0.97	6400	2905.60	1008.28
100	2.54	-40	-1.02	6600	2996.40	1039.79
120	3.05	-42	-1.07	6800	3087.20	1071.30
140	3.56	-45	-1.14	7000	3178.00	1102.81
160	4.06	-46	-1.17	7200	3268.80	1134.32
180	4.57	-48	-1.22	7400	3359.60	1165.83
200	5.08	-50	-1.27	7600	3450.40	1197.33
250	6.35	-52	-1.32	8000	3632.00	1260.35
300	7.62	-55	-1.40	8200	3722.80	1291.86
350	8.89	-58	-1.47	8200	3722.80	1291.86
400	10.16	-60	-1.52	8000	3632.00	1260.35
450	11.43	-62	-1.57	8000	3632.00	1260.35
500	12.70	-65	-1.65	8000	3632.00	1260.35
550	13.97	-67	-1.70	8000	3632.00	1260.35
600	15.24	-69	-1.75	8000	3632.00	1260.35

Table A.69 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 7.97% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-8	-0.20	1400	635.60	220.56
20	0.51	-9	-0.23	2000	908.00	315.09
30	0.76	-10	-0.25	2000	908.00	315.09
40	1.02	-10	-0.25	2400	1089.60	378.11
50	1.27	-11	-0.28	2600	1180.40	409.61
60	1.52	-10	-0.25	2700	1225.80	425.37
70	1.78	-10	-0.25	2800	1271.20	441.12
80	2.03	-10	-0.25	2900	1316.60	456.88
90	2.29	-10	-0.25	3000	1362.00	472.63
100	2.54	-10	-0.25	3000	1362.00	472.63
120	3.05	-10	-0.25	3000	1362.00	472.63
140	3.56	-10	-0.25	3000	1362.00	472.63
160	4.06	-11	-0.28	3000	1362.00	472.63
180	4.57	-11	-0.28	3000	1362.00	472.63
200	5.08	-11	-0.28	3000	1362.00	472.63
250	6.35	-11	-0.28	3000	1362.00	472.63
300	7.62	-11	-0.28	2800	1271.20	441.12
350	8.89	-12	-0.30	2800	1271.20	441.12
400	10.16	-12	-0.30	2600	1180.40	409.61
450	11.43	-12	-0.30	2600	1180.40	409.61
500	12.70	-12	-0.30	2600	1180.40	409.61
550	13.97	-12	-0.30	2600	1180.40	409.61
600	15.24	-12	-0.30	2600	1180.40	409.61

Table A.70 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 7.32% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-5	-0.13	1400	635.60	220.56
20	0.51	-7	-0.18	2200	998.80	346.60
30	0.76	-10	-0.25	2600	1180.40	409.61
40	1.02	-11	-0.28	3000	1362.00	472.63
50	1.27	-13	-0.33	3400	1543.60	535.65
60	1.52	-16	-0.41	3400	1543.60	535.65
70	1.78	-17	-0.43	3800	1725.20	598.67
80	2.03	-18	-0.46	4000	1816.00	630.18
90	2.29	-20	-0.51	4000	1816.00	630.18
100	2.54	-21	-0.53	4000	1816.00	630.18
120	3.05	-22	-0.56	4200	1906.80	661.68
140	3.56	-24	-0.61	4200	1906.80	661.68
160	4.06	-25	-0.64	4400	1997.60	693.19
180	4.57	-25	-0.64	4600	2088.40	724.70
200	5.08	-26	-0.66	4600	2088.40	724.70
250	6.35	-27	-0.69	4600	2088.40	724.70
300	7.62	-28	-0.71	4600	2088.40	724.70
350	8.89	-29	-0.74	4600	2088.40	724.70
400	10.16	-30	-0.76	4600	2088.40	724.70
450	11.43	-31	-0.79	4600	2088.40	724.70
500	12.70	-32	-0.81	4500	2043.00	708.95
550	13.97	-33	-0.84	4400	1997.60	693.19
600	15.24	-33	-0.84	4400	1997.60	693.19

Table A.71 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 7.45% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-13	-0.33	2800	1271.20	441.12
20	0.51	-15	-0.38	3600	1634.40	567.16
30	0.76	-17	-0.43	3800	1725.20	598.67
40	1.02	-19	-0.48	3900	1770.60	614.42
50	1.27	-20	-0.51	4000	1816.00	630.18
60	1.52	-21	-0.53	4200	1906.80	661.68
70	1.78	-22	-0.56	4800	2179.20	756.21
80	2.03	-23	-0.58	4900	2224.60	771.97
90	2.29	-24	-0.61	5000	2270.00	787.72
100	2.54	-24	-0.61	5100	2315.40	803.47
120	3.05	-25	-0.64	5200	2360.80	819.23
140	3.56	-26	-0.66	5400	2451.60	850.74
160	4.06	-27	-0.69	5600	2542.40	882.25
180	4.57	-29	-0.74	5800	2633.20	913.75
200	5.08	-31	-0.79	6000	2724.00	945.26
250	6.35	-34	-0.86	6100	2769.40	961.02
300	7.62	-38	-0.97	6100	2769.40	961.02
350	8.89	-40	-1.02	6100	2769.40	961.02
400	10.16	-42	-1.07	6100	2769.40	961.02
450	11.43	-43	-1.09	6100	2769.40	961.02
500	12.70	-44	-1.12	6000	2724.00	945.26
550	13.97	-46	-1.17	6000	2724.00	945.26
600	15.24	-48	-1.22	6000	2724.00	945.26

Table A.72 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 7.56% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-14	-0.36	1800	817.20	283.58
20	0.51	-16	-0.41	2600	1180.40	409.61
30	0.76	-18	-0.46	3600	1634.40	567.16
40	1.02	-20	-0.51	4000	1816.00	630.18
50	1.27	-23	-0.58	4600	2088.40	724.70
60	1.52	-26	-0.66	5200	2360.80	819.23
70	1.78	-28	-0.71	5400	2451.60	850.74
80	2.03	-30	-0.76	5600	2542.40	882.25
90	2.29	-33	-0.84	6000	2724.00	945.26
100	2.54	-35	-0.89	6200	2814.80	976.77
120	3.05	-37	-0.94	6400	2905.60	1008.28
140	3.56	-38	-0.97	6600	2996.40	1039.79
160	4.06	-40	-1.02	6800	3087.20	1071.30
180	4.57	-43	-1.09	7000	3178.00	1102.81
200	5.08	-46	-1.17	7200	3268.80	1134.32
250	6.35	-49	-1.24	7400	3359.60	1165.83
300	7.62	-51	-1.30	7600	3450.40	1197.33
350	8.89	-53	-1.35	7600	3450.40	1197.33
400	10.16	-55	-1.40	7600	3450.40	1197.33
450	11.43	-56	-1.42	7600	3450.40	1197.33
500	12.70	-57	-1.45	7600	3450.40	1197.33
550	13.97	-60	-1.52	7600	3450.40	1197.33
600	15.24	-61	-1.55	7600	3450.40	1197.33

Table A.73 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 9.98% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-6	-0.15	2000	908.00	315.25
20	0.51	-12	-0.30	2200	998.80	346.78
30	0.76	-15	-0.38	2300	1044.20	362.54
40	1.02	-20	-0.51	2400	1089.60	378.30
50	1.27	-23	-0.58	2500	1135.00	394.07
60	1.52	-25	-0.64	2700	1225.80	425.59
70	1.78	-26	-0.66	2800	1271.20	441.35
80	2.03	-27	-0.69	2900	1316.60	457.12
90	2.29	-28	-0.71	3000	1362.00	472.88
100	2.54	-30	-0.76	3000	1362.00	472.88
120	3.05	-30	-0.76	3000	1362.00	472.88
140	3.56	-31	-0.79	3000	1362.00	472.88
160	4.06	-32	-0.81	3000	1362.00	472.88
180	4.57	-33	-0.84	3000	1362.00	472.88
200	5.08	-34	-0.86	3000	1362.00	472.88
250	6.35	-35	-0.89	3000	1362.00	472.88
300	7.62	-36	-0.91	3000	1362.00	472.88
350	8.89	-37	-0.94	3000	1362.00	472.88
400	10.16	-38	-0.97	3000	1362.00	472.88
450	11.43	-39	-0.99	3000	1362.00	472.88
500	12.70	-41	-1.04	3000	1362.00	472.88
550	13.97	-42	-1.07	3000	1362.00	472.88
600	15.24	-43	-1.09	3000	1362.00	472.88

Table A.74 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 10.05% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-11	-0.28	2000	908.00	315.25
20	0.51	-17	-0.43	2600	1180.40	409.83
30	0.76	-20	-0.51	2800	1271.20	441.35
40	1.02	-25	-0.64	3200	1452.80	504.40
50	1.27	-26	-0.66	3500	1589.00	551.69
60	1.52	-28	-0.71	3700	1679.80	583.22
70	1.78	-29	-0.74	3900	1770.60	614.74
80	2.03	-32	-0.81	4100	1861.40	646.27
90	2.29	-34	-0.86	4300	1952.20	677.79
100	2.54	-36	-0.91	4300	1952.20	677.79
120	3.05	-38	-0.97	4300	1952.20	677.79
140	3.56	-40	-1.02	4300	1952.20	677.79
160	4.06	-42	-1.07	4300	1952.20	677.79
180	4.57	-43	-1.09	4300	1952.20	677.79
200	5.08	-44	-1.12	4300	1952.20	677.79
250	6.35	-46	-1.17	4300	1952.20	677.79
300	7.62	-47	-1.19	4300	1952.20	677.79
350	8.89	-48	-1.22	4300	1952.20	677.79
400	10.16	-50	-1.27	4300	1952.20	677.79
450	11.43	-52	-1.32	4300	1952.20	677.79
500	12.70	-54	-1.37	4300	1952.20	677.79
550	13.97	-56	-1.42	4300	1952.20	677.79
600	15.24	-56	-1.42	4300	1952.20	677.79

Table A.75 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 10.74% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-12	-0.30	3300	1498.20	520.17
20	0.51	-14	-0.36	4100	1861.40	646.27
30	0.76	-16	-0.41	4300	1952.20	677.79
40	1.02	-20	-0.51	4400	1997.60	693.56
50	1.27	-25	-0.64	4600	2088.40	725.08
60	1.52	-30	-0.76	4800	2179.20	756.61
70	1.78	-34	-0.86	5000	2270.00	788.13
80	2.03	-38	-0.97	5200	2360.80	819.66
90	2.29	-42	-1.07	5300	2406.20	835.42
100	2.54	-44	-1.12	5300	2406.20	835.42
120	3.05	-46	-1.17	5500	2497.00	866.94
140	3.56	-48	-1.22	5500	2497.00	866.94
160	4.06	-51	-1.30	5500	2497.00	866.94
180	4.57	-53	-1.35	5700	2587.80	898.47
200	5.08	-55	-1.40	5700	2587.80	898.47
250	6.35	-58	-1.47	5700	2587.80	898.47
300	7.62	-60	-1.52	5700	2587.80	898.47
350	8.89	-63	-1.60	5700	2587.80	898.47
400	10.16	-65	-1.65	5700	2587.80	898.47
450	11.43	-68	-1.73	5700	2587.80	898.47
500	12.70	-70	-1.78	5700	2587.80	898.47
550	13.97	-72	-1.83	5700	2587.80	898.47
600	15.24	-74	-1.88	5700	2587.80	898.47

Table A.76 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 10.74% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-23	-0.58	2500	1135.00	394.07
20	0.51	-25	-0.64	3300	1498.20	520.17
30	0.76	-27	-0.69	4300	1952.20	677.79
40	1.02	-31	-0.79	4700	2133.80	740.84
50	1.27	-36	-0.91	5300	2406.20	835.42
60	1.52	-41	-1.04	5900	2678.60	929.99
70	1.78	-45	-1.14	6100	2769.40	961.52
80	2.03	-49	-1.24	6300	2860.20	993.05
90	2.29	-53	-1.35	6500	2951.00	1024.57
100	2.54	-55	-1.40	6700	3041.80	1056.10
120	3.05	-57	-1.45	6800	3087.20	1071.86
140	3.56	-59	-1.50	6900	3132.60	1087.62
160	4.06	-62	-1.57	6900	3132.60	1087.62
180	4.57	-64	-1.63	6900	3132.60	1087.62
200	5.08	-66	-1.68	6900	3132.60	1087.62
250	6.35	-69	-1.75	6900	3132.60	1087.62
300	7.62	-71	-1.80	6900	3132.60	1087.62
350	8.89	-74	-1.88	6900	3132.60	1087.62
400	10.16	-76	-1.93	6900	3132.60	1087.62
450	11.43	-79	-2.01	6900	3132.60	1087.62
500	12.70	-81	-2.06	6900	3132.60	1087.62
550	13.97	-83	-2.11	6900	3132.60	1087.62
600	15.24	-85	-2.16	6900	3132.60	1087.62

Table A.77 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 12.68% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-6	-0.15	1000	454.00	157.63
20	0.51	-12	-0.30	1200	544.80	189.15
30	0.76	-15	-0.38	1300	590.20	204.91
40	1.02	-20	-0.51	1400	635.60	220.68
50	1.27	-23	-0.58	1500	681.00	236.44
60	1.52	-25	-0.64	1700	771.80	267.96
70	1.78	-26	-0.66	1800	817.20	283.73
80	2.03	-27	-0.69	1900	862.60	299.49
90	2.29	-28	-0.71	2000	908.00	315.25
100	2.54	-30	-0.76	2100	953.40	331.02
120	3.05	-30	-0.76	2200	998.80	346.78
140	3.56	-31	-0.79	2300	1044.20	362.54
160	4.06	-32	-0.81	2400	1089.60	378.30
180	4.57	-33	-0.84	2500	1135.00	394.07
200	5.08	-34	-0.86	2600	1180.40	409.83
250	6.35	-35	-0.89	2800	1271.20	441.35
300	7.62	-36	-0.91	2800	1271.20	441.35
350	8.89	-37	-0.94	2800	1271.20	441.35
400	10.16	-38	-0.97	2800	1271.20	441.35
450	11.43	-39	-0.99	2800	1271.20	441.35
500	12.70	-41	-1.04	2800	1271.20	441.35
550	13.97	-42	-1.07	2800	1271.20	441.35
600	15.24	-43	-1.09	2800	1271.20	441.35

Table A.78 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 12.41% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-11	-0.28	1300	590.20	204.91
20	0.51	-17	-0.43	1900	862.60	299.49
30	0.76	-20	-0.51	2100	953.40	331.02
40	1.02	-25	-0.64	2500	1135.00	394.07
50	1.27	-26	-0.66	2800	1271.20	441.35
60	1.52	-28	-0.71	3000	1362.00	472.88
70	1.78	-29	-0.74	3200	1452.80	504.40
80	2.03	-32	-0.81	3400	1543.60	535.93
90	2.29	-34	-0.86	3600	1634.40	567.45
100	2.54	-36	-0.91	3700	1679.80	583.22
120	3.05	-38	-0.97	3700	1679.80	583.22
140	3.56	-40	-1.02	3700	1679.80	583.22
160	4.06	-42	-1.07	3700	1679.80	583.22
180	4.57	-43	-1.09	3700	1679.80	583.22
200	5.08	-44	-1.12	3700	1679.80	583.22
250	6.35	-46	-1.17	3700	1679.80	583.22
300	7.62	-47	-1.19	3700	1679.80	583.22
350	8.89	-48	-1.22	3700	1679.80	583.22
400	10.16	-50	-1.27	3700	1679.80	583.22
450	11.43	-52	-1.32	3700	1679.80	583.22
500	12.70	-54	-1.37	3700	1679.80	583.22
550	13.97	-56	-1.42	3700	1679.80	583.22
600	15.24	-56	-1.42	3700	1679.80	583.22

Table A.79 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 12.18% of normal stress is 1054.51 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-18	-0.46	2500	1135.00	394.07
20	0.51	-22	-0.56	3300	1498.20	520.17
30	0.76	-26	-0.66	3500	1589.00	551.69
40	1.02	-30	-0.76	3600	1634.40	567.45
50	1.27	-35	-0.89	3800	1725.20	598.98
60	1.52	-40	-1.02	4000	1816.00	630.50
70	1.78	-44	-1.12	4200	1906.80	662.03
80	2.03	-48	-1.22	4400	1997.60	693.56
90	2.29	-52	-1.32	4500	2043.00	709.32
100	2.54	-54	-1.37	4500	2043.00	709.32
120	3.05	-56	-1.42	4700	2133.80	740.84
140	3.56	-58	-1.47	4700	2133.80	740.84
160	4.06	-61	-1.55	4700	2133.80	740.84
180	4.57	-63	-1.60	4900	2224.60	772.37
200	5.08	-65	-1.65	4900	2224.60	772.37
250	6.35	-68	-1.73	4900	2224.60	772.37
300	7.62	-70	-1.78	4900	2224.60	772.37
350	8.89	-73	-1.85	4900	2224.60	772.37
400	10.16	-75	-1.91	4900	2224.60	772.37
450	11.43	-78	-1.98	4900	2224.60	772.37
500	12.70	-80	-2.03	4900	2224.60	772.37
550	13.97	-82	-2.08	4900	2224.60	772.37
600	15.24	-84	-2.13	4900	2224.60	772.37

Table A.80 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 12.12% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-12	-0.30	1600	726.40	252.20
20	0.51	-16	-0.41	2200	998.80	346.78
30	0.76	-20	-0.51	3200	1452.80	504.40
40	1.02	-24	-0.61	3600	1634.40	567.45
50	1.27	-29	-0.74	4200	1906.80	662.03
60	1.52	-34	-0.86	4800	2179.20	756.61
70	1.78	-38	-0.97	5000	2270.00	788.13
80	2.03	-42	-1.07	5200	2360.80	819.66
90	2.29	-46	-1.17	5600	2542.40	882.71
100	2.54	-48	-1.22	5700	2587.80	898.47
120	3.05	-50	-1.27	5800	2633.20	914.23
140	3.56	-52	-1.32	5900	2678.60	929.99
160	4.06	-55	-1.40	6000	2724.00	945.76
180	4.57	-57	-1.45	6000	2724.00	945.76
200	5.08	-59	-1.50	6000	2724.00	945.76
250	6.35	-62	-1.57	6000	2724.00	945.76
300	7.62	-64	-1.63	6000	2724.00	945.76
350	8.89	-67	-1.70	6000	2724.00	945.76
400	10.16	-69	-1.75	6000	2724.00	945.76
450	11.43	-72	-1.83	6000	2724.00	945.76
500	12.70	-74	-1.88	6000	2724.00	945.76
550	13.97	-76	-1.93	6000	2724.00	945.76
600	15.24	-78	-1.98	6000	2724.00	945.76

Table A.81 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 14.29% of normal stress is 351.50 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-6	-0.15	1000	454.00	157.63
20	0.51	-12	-0.30	1100	499.40	173.39
30	0.76	-15	-0.38	1200	544.80	189.15
40	1.02	-20	-0.51	1300	590.20	204.91
50	1.27	-30	-0.76	1400	635.60	220.68
60	1.52	-37	-0.94	1600	726.40	252.20
70	1.78	-41	-1.04	1700	771.80	267.96
80	2.03	-49	-1.24	1800	817.20	283.73
90	2.29	-54	-1.37	1900	862.60	299.49
100	2.54	-59	-1.50	2000	908.00	315.25
120	3.05	-67	-1.70	2100	953.40	331.02
140	3.56	-73	-1.85	2200	998.80	346.78
160	4.06	-79	-2.01	2200	998.80	346.78
180	4.57	-85	-2.16	2200	998.80	346.78
200	5.08	-90	-2.29	2200	998.80	346.78
250	6.35	-98	-2.49	2200	998.80	346.78
300	7.62	-102	-2.59	2200	998.80	346.78
350	8.89	-105	-2.67	2200	998.80	346.78
400	10.16	-108	-2.74	2200	998.80	346.78
450	11.43	-110	-2.79	2200	998.80	346.78
500	12.70	-112	-2.84	2200	998.80	346.78
550	13.97	-114	-2.90	2200	998.80	346.78
600	15.24	-115	-2.92	2200	998.80	346.78

Table A.82 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 14.83% of normal stress is 703.01 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-11	-0.28	1000	454.00	157.63
20	0.51	-17	-0.43	1300	590.20	204.91
30	0.76	-20	-0.51	1400	635.60	220.68
40	1.02	-25	-0.64	1400	635.60	220.68
50	1.27	-35	-0.89	1500	681.00	236.44
60	1.52	-42	-1.07	1700	771.80	267.96
70	1.78	-46	-1.17	1800	817.20	283.73
80	2.03	-54	-1.37	2000	908.00	315.25
90	2.29	-59	-1.50	2100	953.40	331.02
100	2.54	-64	-1.63	2200	998.80	346.78
120	3.05	-72	-1.83	2300	1044.20	362.54
140	3.56	-78	-1.98	2400	1089.60	378.30
160	4.06	-84	-2.13	2600	1180.40	409.83
180	4.57	-90	-2.29	2800	1271.20	441.35
200	5.08	-95	-2.41	3000	1362.00	472.88
250	6.35	-103	-2.62	3200	1452.80	504.40
300	7.62	-107	-2.72	3200	1452.80	504.40
350	8.89	-110	-2.79	3200	1452.80	504.40
400	10.16	-113	-2.87	3200	1452.80	504.40
450	11.43	-115	-2.92	3200	1452.80	504.40
500	12.70	-117	-2.97	3200	1452.80	504.40
550	13.97	-119	-3.02	3200	1452.80	504.40
600	15.24	-120	-3.05	3200	1452.80	504.40

Table A.83 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 15.10% of normal stress is 1054.51 kPa.

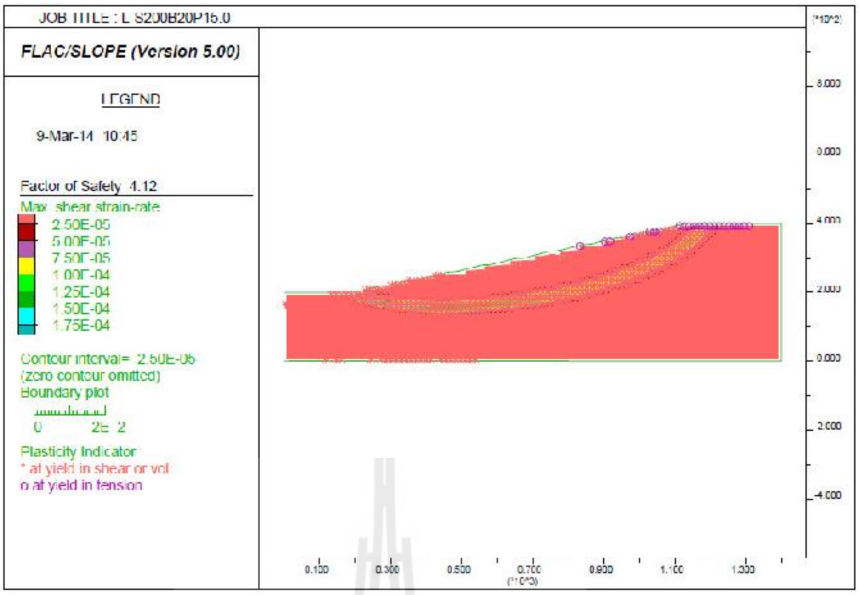
Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-18	-0.46	1200	544.80	189.15
20	0.51	-24	-0.61	1400	635.60	220.68
30	0.76	-27	-0.69	1600	726.40	252.20
40	1.02	-32	-0.81	1800	817.20	283.73
50	1.27	-42	-1.07	2000	908.00	315.25
60	1.52	-49	-1.24	2200	998.80	346.78
70	1.78	-53	-1.35	2400	1089.60	378.30
80	2.03	-61	-1.55	2600	1180.40	409.83
90	2.29	-66	-1.68	2800	1271.20	441.35
100	2.54	-71	-1.80	3000	1362.00	472.88
120	3.05	-79	-2.01	3200	1452.80	504.40
140	3.56	-85	-2.16	3400	1543.60	535.93
160	4.06	-91	-2.31	3600	1634.40	567.45
180	4.57	-97	-2.46	3800	1725.20	598.98
200	5.08	-102	-2.59	4000	1816.00	630.50
250	6.35	-110	-2.79	4100	1861.40	646.27
300	7.62	-114	-2.90	4100	1861.40	646.27
350	8.89	-117	-2.97	4100	1861.40	646.27
400	10.16	-120	-3.05	4100	1861.40	646.27
450	11.43	-122	-3.10	4100	1861.40	646.27
500	12.70	-124	-3.15	4100	1861.40	646.27
550	13.97	-126	-3.20	4100	1861.40	646.27
600	15.24	-127	-3.23	4100	1861.40	646.27

Table A.84 Large-scale direct shear test with soil sample passing sieve opening ¾ in at water content about 14.94% of normal stress is 1406.02 kPa.

Horizontal reading (div.)	Horizontal displacement (mm)	Vertical reading (div.)	Vertical displacement (mm)	Load reading (Ib)	Shear force (kg)	Shear Stress (kPa)
0	0.00	0	0.00	0	0.00	0.00
10	0.25	-10	-0.25	1600	726.40	252.20
20	0.51	-18	-0.46	2100	953.40	331.02
30	0.76	-26	-0.66	3100	1407.40	488.64
40	1.02	-35	-0.89	3500	1589.00	551.69
50	1.27	-45	-1.14	3800	1725.20	598.98
60	1.52	-50	-1.27	4000	1816.00	630.50
70	1.78	-54	-1.37	4100	1861.40	646.27
80	2.03	-61	-1.55	4200	1906.80	662.03
90	2.29	-68	-1.73	4400	1997.60	693.56
100	2.54	-72	-1.83	4500	2043.00	709.32
120	3.05	-74	-1.88	4600	2088.40	725.08
140	3.56	-78	-1.98	4800	2179.20	756.61
160	4.06	-88	-2.24	5000	2270.00	788.13
180	4.57	-99	-2.51	5000	2270.00	788.13
200	5.08	-105	-2.67	5000	2270.00	788.13
250	6.35	-117	-2.97	5000	2270.00	788.13
300	7.62	-119	-3.02	5000	2270.00	788.13
350	8.89	-123	-3.12	5000	2270.00	788.13
400	10.16	-126	-3.20	5000	2270.00	788.13
450	11.43	-136	-3.45	5000	2270.00	788.13
500	12.70	-140	-3.56	5000	2270.00	788.13
550	13.97	-146	-3.71	5000	2270.00	788.13
600	15.24	-150	-3.81	5000	2270.00	788.13

APPENDIX B

NUMERICAL ANALYSIS RESULTS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Factor of Safety 4.12
Max. shear strain-rate
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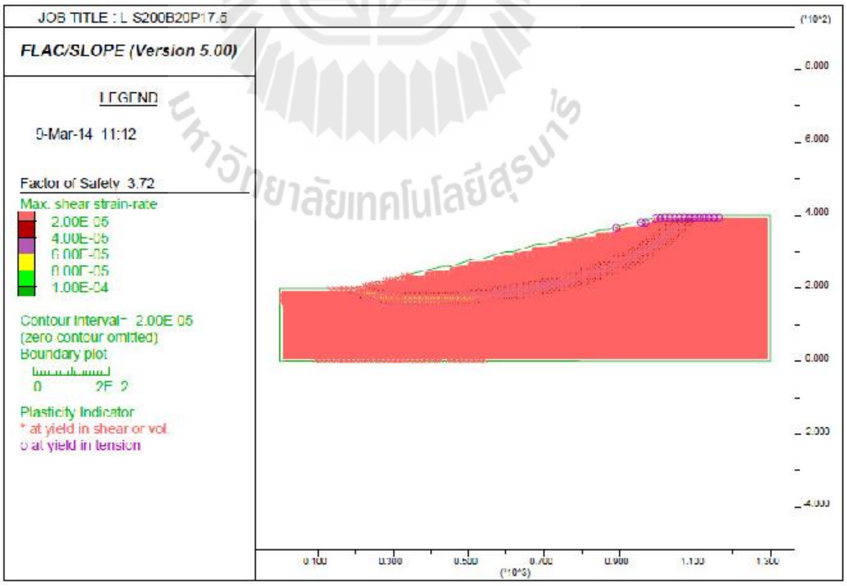
5.00E-05
7.50E-05
1.00E-04
1.25E-04
1.50E-04
1.75E-04
Contour interval= 2.50E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol
o at yield in tension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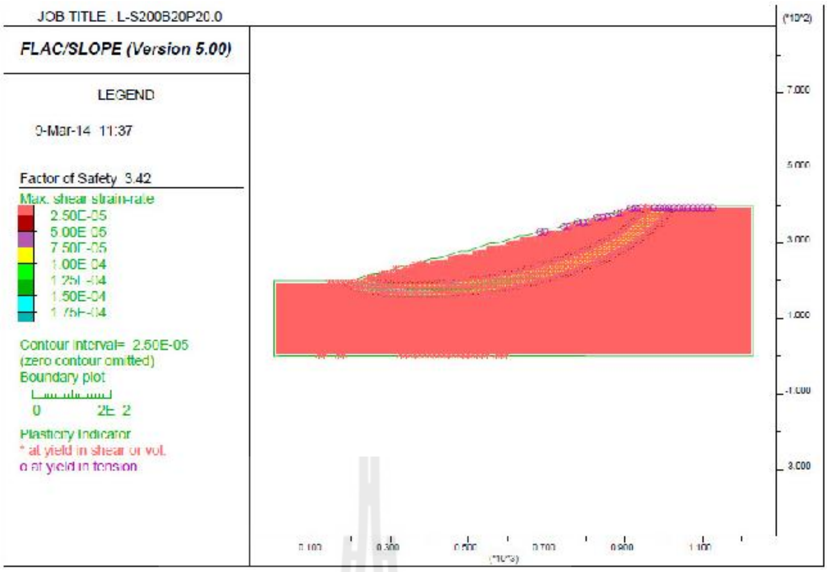
Factor of Safety 3.72
Max. shear strain-rate
2.00E-05
4.00E-05
1.00E-04
Contour interval= 2.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol
o at yield in tension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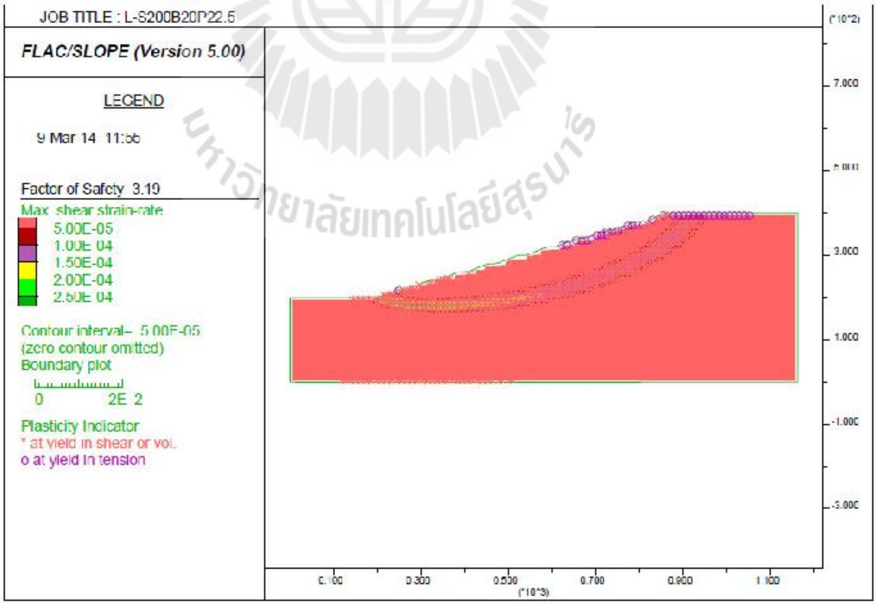
FLAC/SLOPE (Version 5.00)
LEGEND
Factor of Safety 3.42
Max. shear strain-rate
2.50E-05
5.00E-05
7.50E-05
1.00E-04
1.50E-04
Contour interval= 2.50E-05
(zero contour omitted)
Boundary plot
0
2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
7.000
3.000
-1.000
(*10^3)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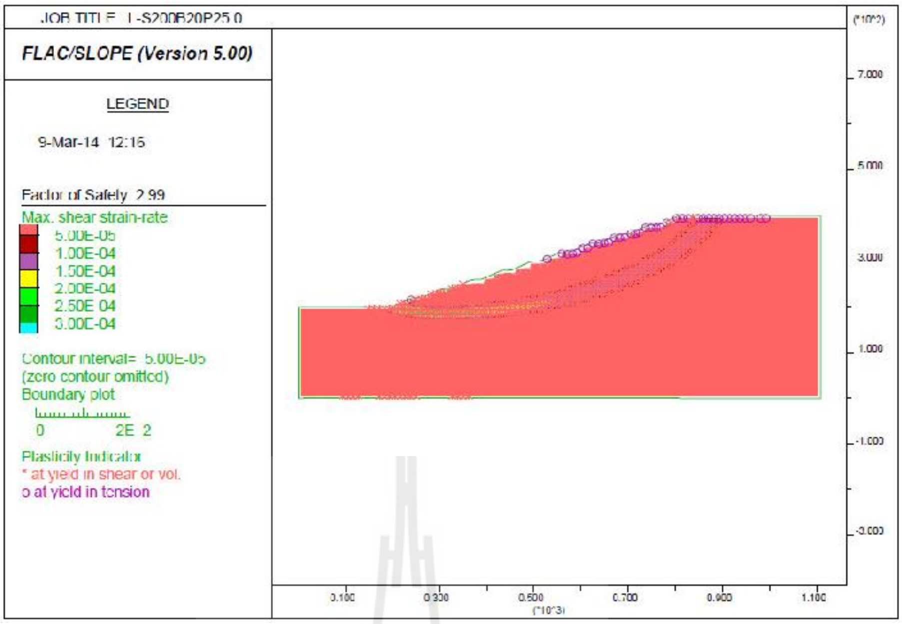
Factor of Safety 3.19
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0
2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
7.000
3.000
1.000
-1.000
-3.000
0.100
0.300
0.500
0.700
0.900
1.100
(*10^3)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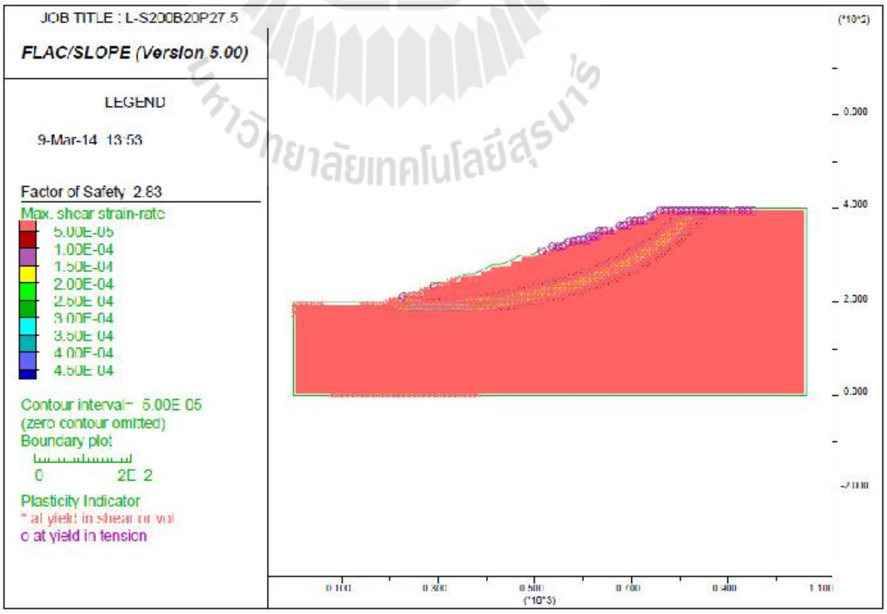
Factor of Safety 2.99
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
7.000
5.000
3.000
1.000
-1.000
-3.000
0.100
0.300
0.500
0.700
0.900
1.100
(*10^3)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Max. shear strain-rate
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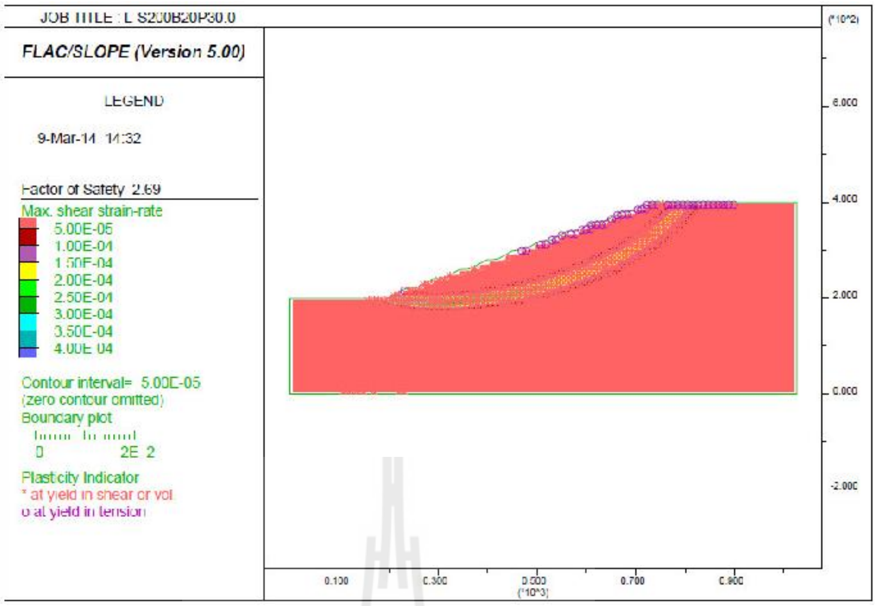
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
3.50E-04
4.00E-04
4.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol
o at yield in tension
(*10^2)
4.300
2.300
0.300
(*10^3)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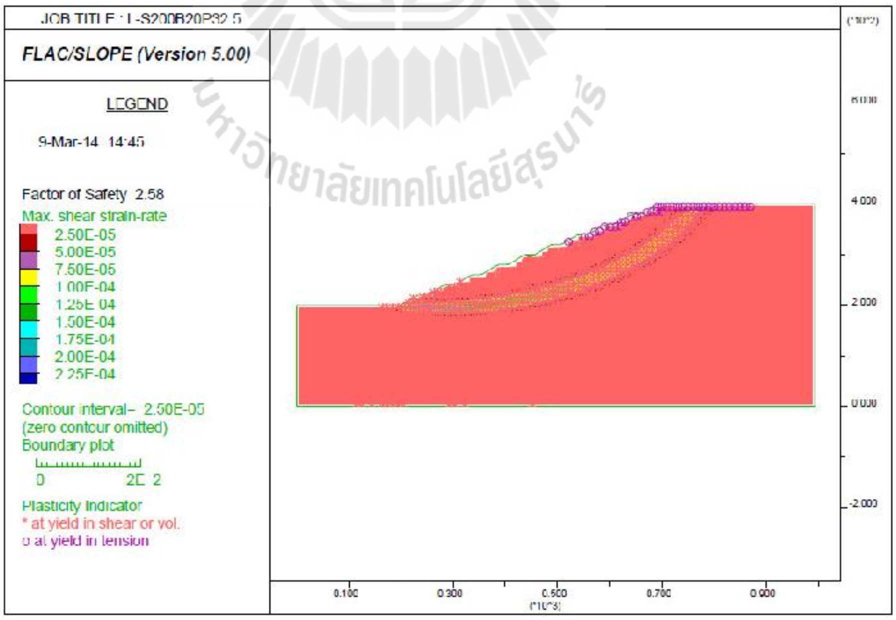
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
3.50E-04
4.00E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol
o at yield in tension
(*10^2)
6.000
4.000
2.000
0.000
-2.000
0.100
0.300
0.500
0.700
0.900
(*10^3)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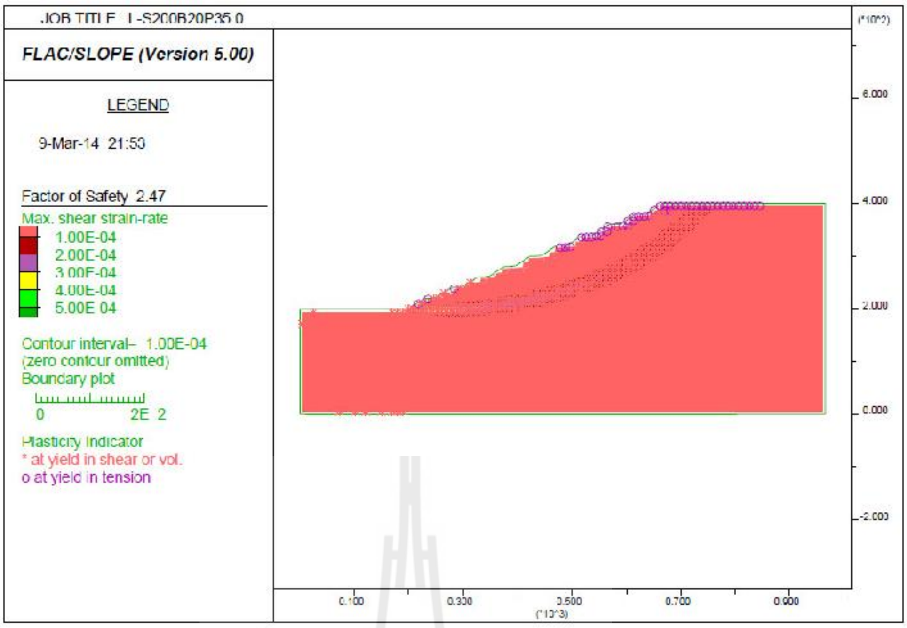
Factor of Safety 2.58
Max. shear strain-rate
2.50E-05
5.00E-05
7.50E-05
1.00E-04
1.25E-04
1.50E-04
1.75E-04
2.00E-04
2.25E-04
Contour interval= 2.50E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
6.000
4.000
2.000
0.000
-2.000
0.100
0.300
0.500
0.700
0.900
(*10^3)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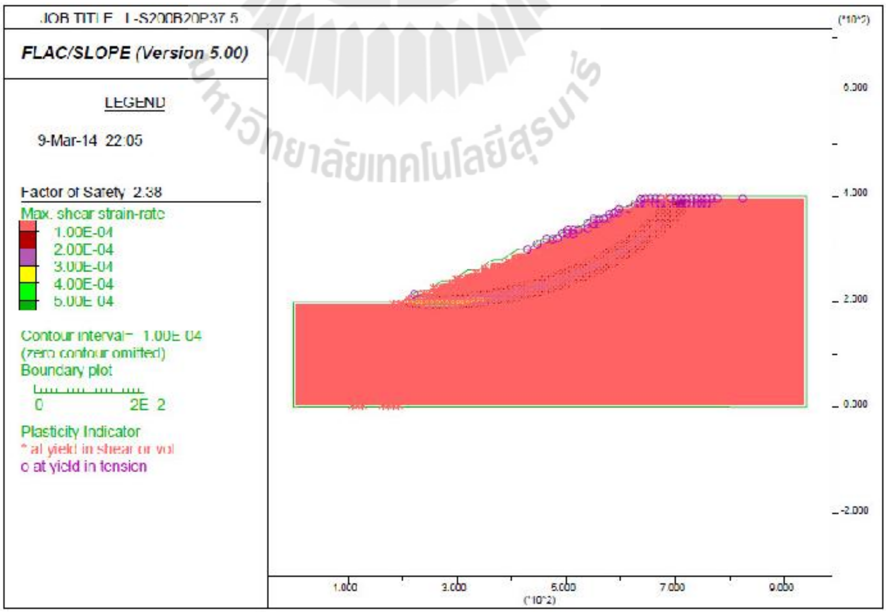
Factor of Safety 2.47
Max. shear strain-rate
1.00E-04
2.00E-04
3.00E-04
4.00E-04
5.00E-04
Contour interval= 1.00E-04
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension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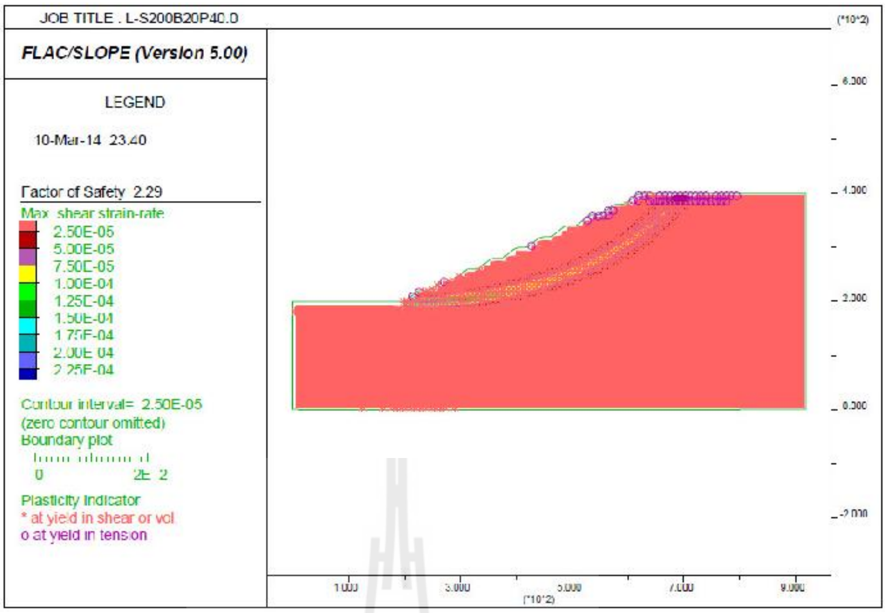
LEGEND
9-Mar-14 22:05
Factor of Safety 2.38
Max. shear strain-rate
1.00E-04
2.00E-04
3.00E-04
4.00E-04
5.00E-04
Contour interval= 1.00E-04
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol
o at yield in tension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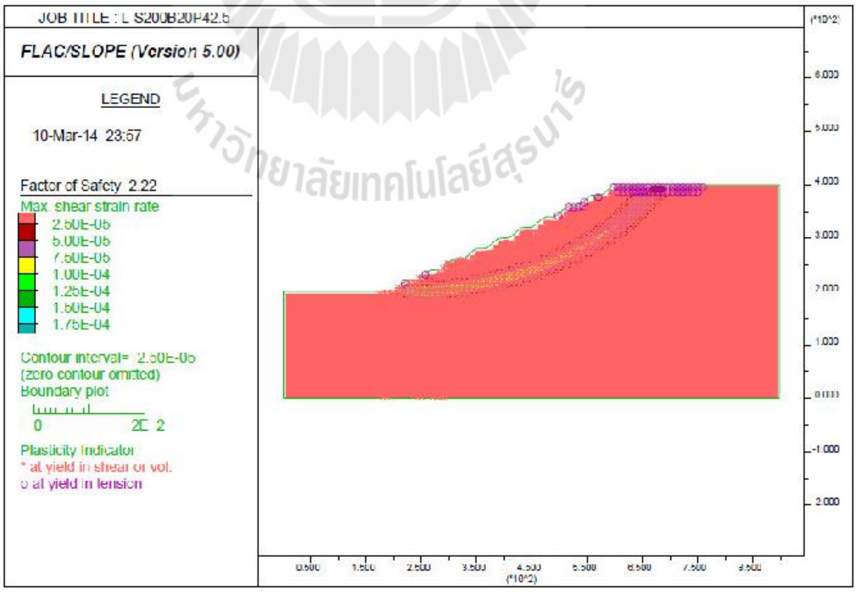
Factor of Safety 2.29
Max. shear strain-rate
2.50E-05
5.00E-05
7.50E-05
1.00E-04
1.25E-04
1.50E-04
1.75E-04
2.00E-04
2.25E-04
Contour interval= 2.50E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
6.000
4.000
2.000
0.000
-2.000
1.000
3.000
5.000
7.000
9.000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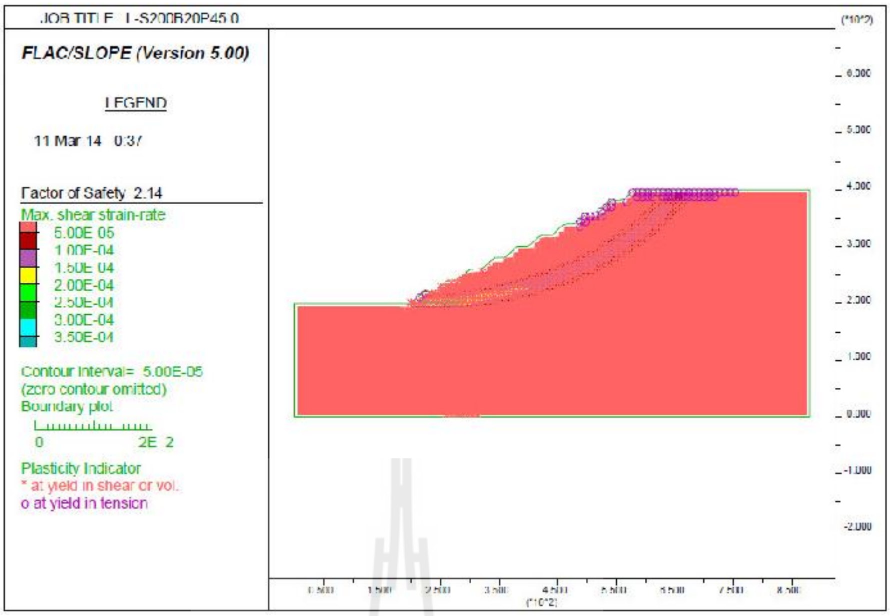
10-Mar-14 23:57
Factor of Safety 2.22
Max. shear strain rate
2.50E-05
5.00E-05
7.50E-05
1.00E-04
1.25E-04
1.50E-04
1.75E-04
Contour interval= 2.50E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
6.000
5.000
4.000
3.000
2.000
1.000
0.000
-1.000
-2.000
0.500
1.500
2.500
3.500
4.500
5.500
6.500
7.500
8.500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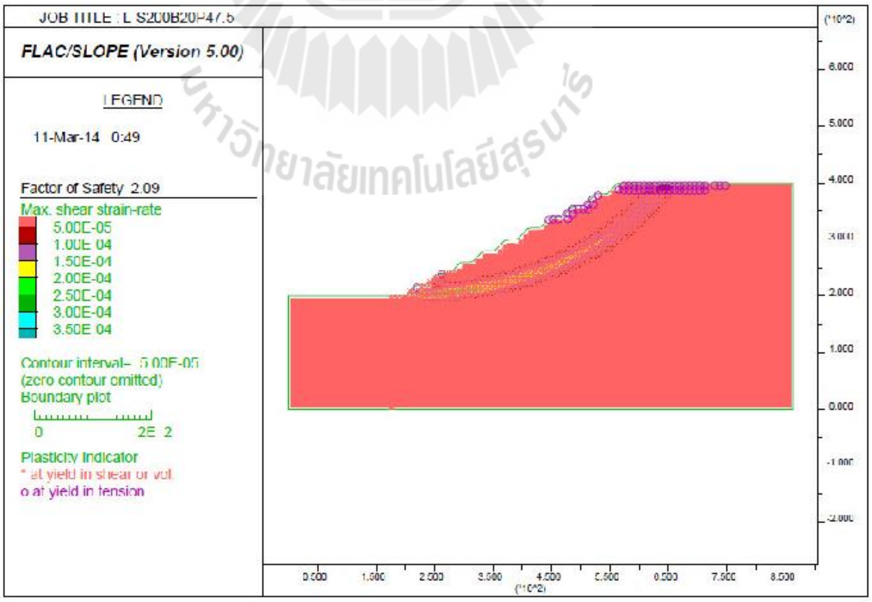
11 Mar 14 0:37
Factor of Safety 2.14
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
3.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension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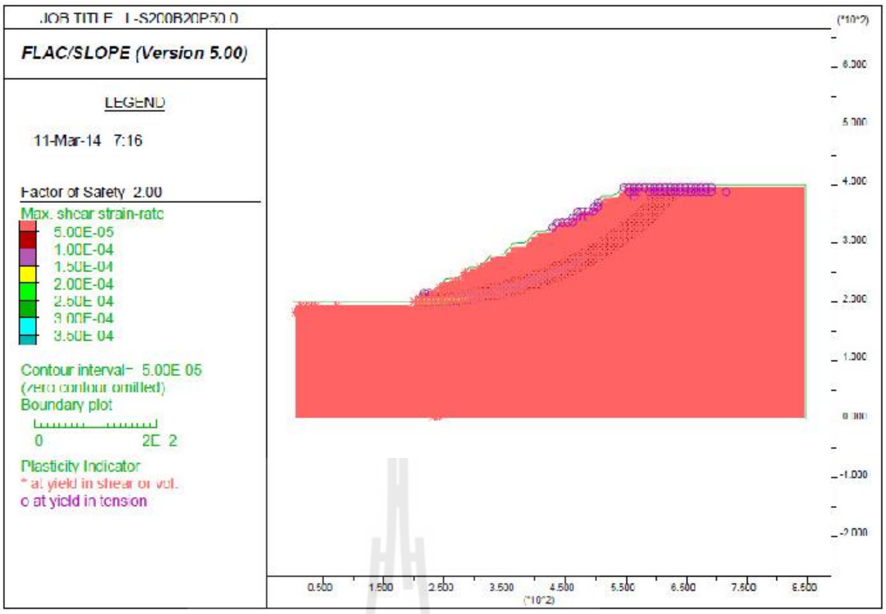
Factor of Safety 2.09
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
3.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension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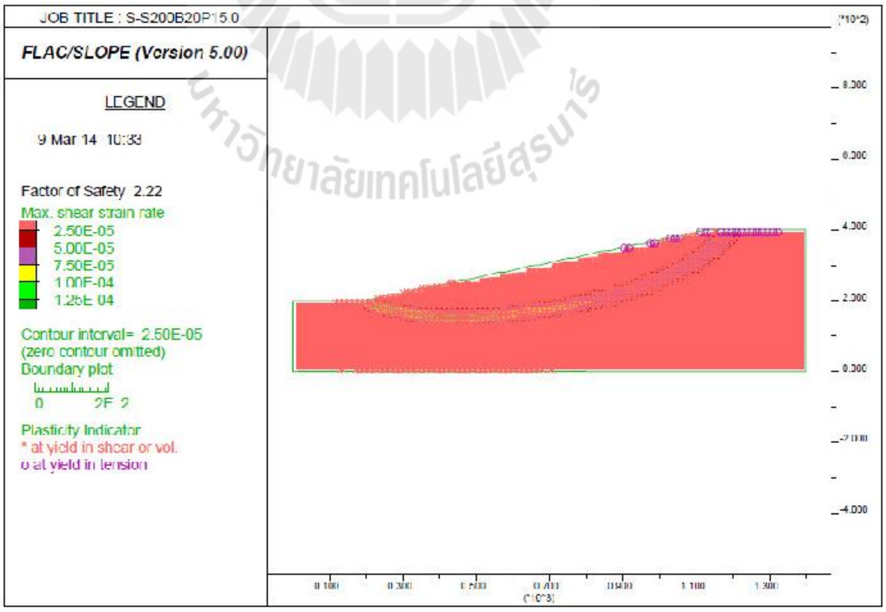
11-Mar-14 7:16
Factor of Safety 2.00
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
3.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension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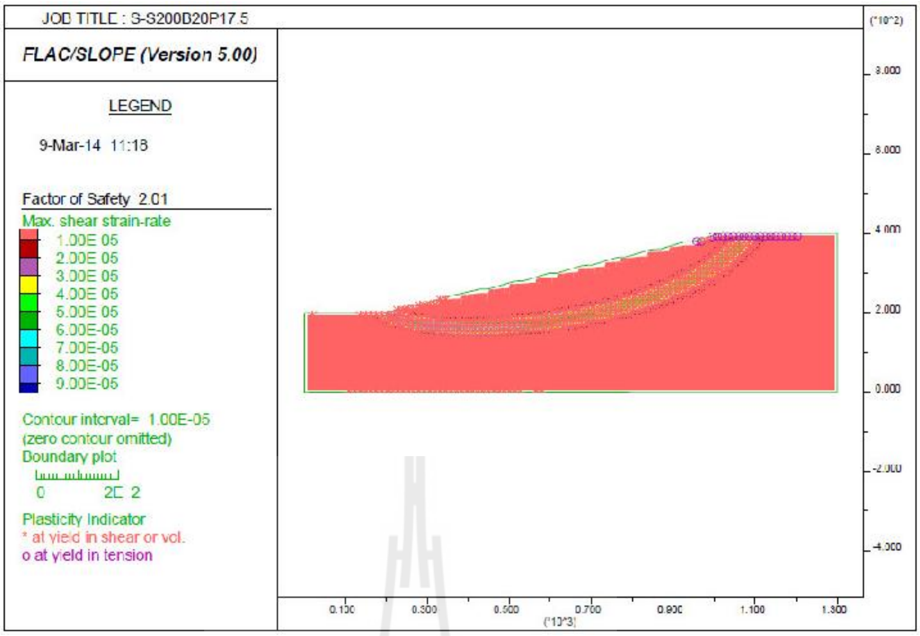
FLAC/SLOPE (Version 5.00)
LEGEND
9-Mar-14 10:33
Factor of Safety 2.22
Max. shear strain rate
2.50E-05
5.00E-05
7.50E-05
1.00E-04
1.25E-04
Contour interval= 2.50E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension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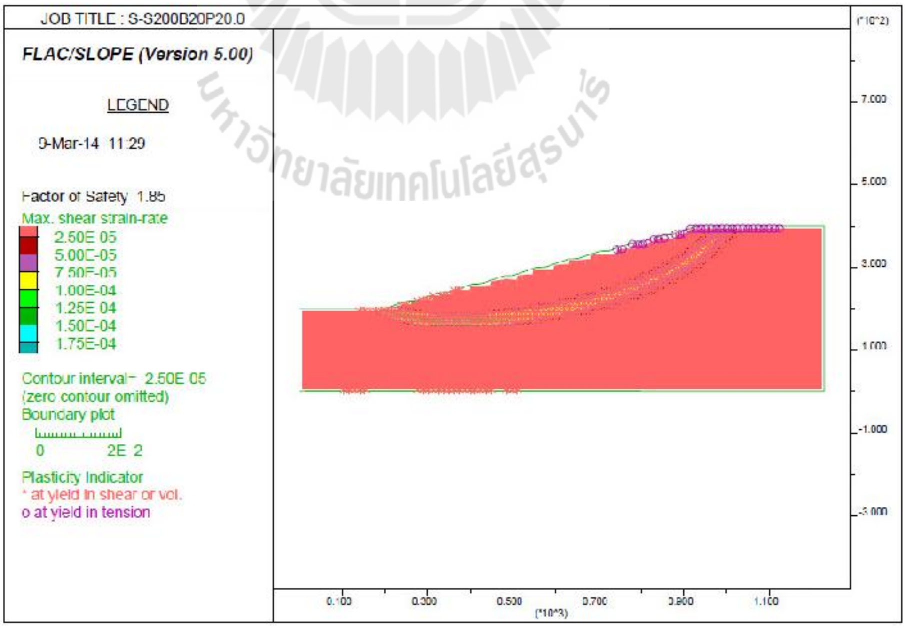
LEGEND
9-Mar-14 11:18
Factor of Safety 2.01
Max. shear strain-rate
1.00E-05
2.00E-05
3.00E-05
4.00E-05
5.00E-05
6.00E-05
7.00E-05
8.00E-05
9.00E-05
Contour interval= 1.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
8.000
6.000
4.000
2.000
0.000
-2.000
-4.000
0.100
0.300
0.500
0.700
0.900
1.100
1.300
(*10^3)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Factor of Safety 1.85
Max. shear strain-rate
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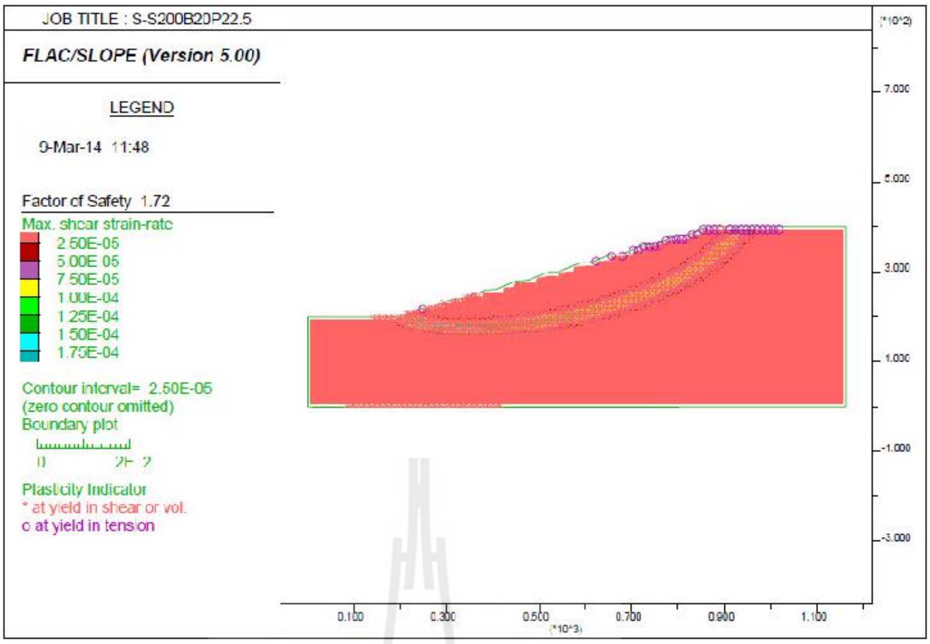
5.00E-05
7.50E-05
1.00E-04
1.25E-04
1.50E-04
1.75E-04
Contour interval= 2.50E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
7.000
5.000
3.000
1.000
-1.000
-3.000
0.100
0.300
0.500
0.700
0.900
1.100
(*10^3)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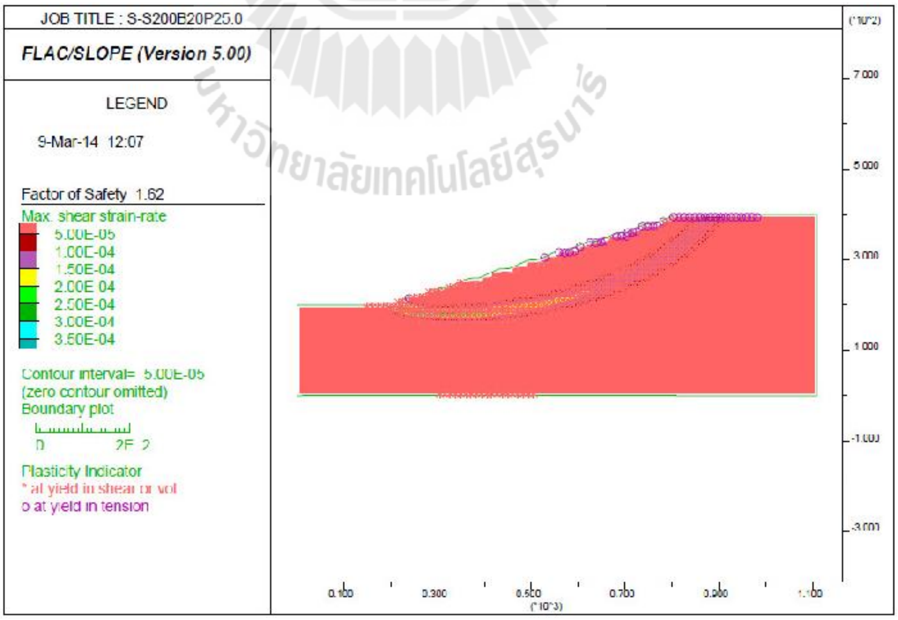
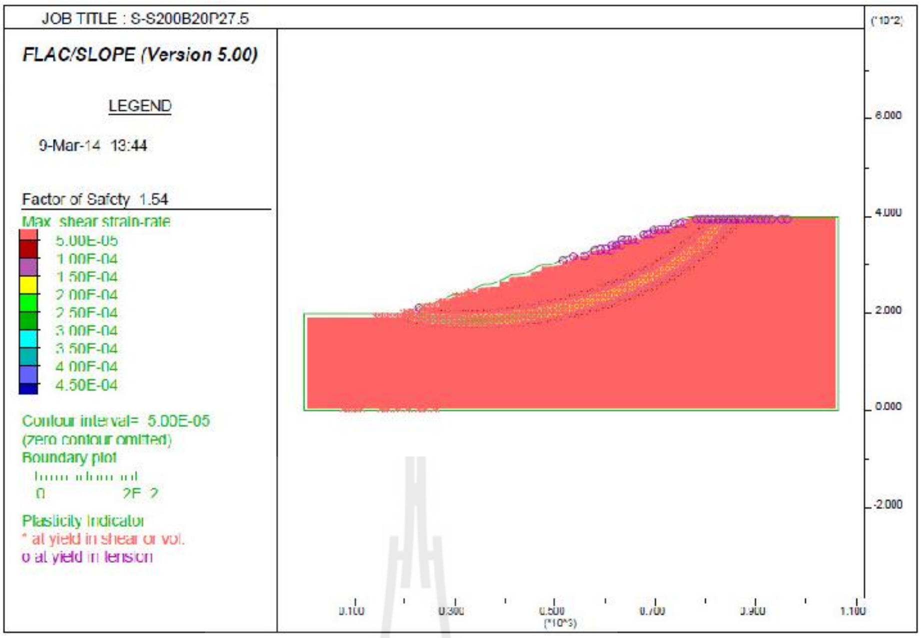
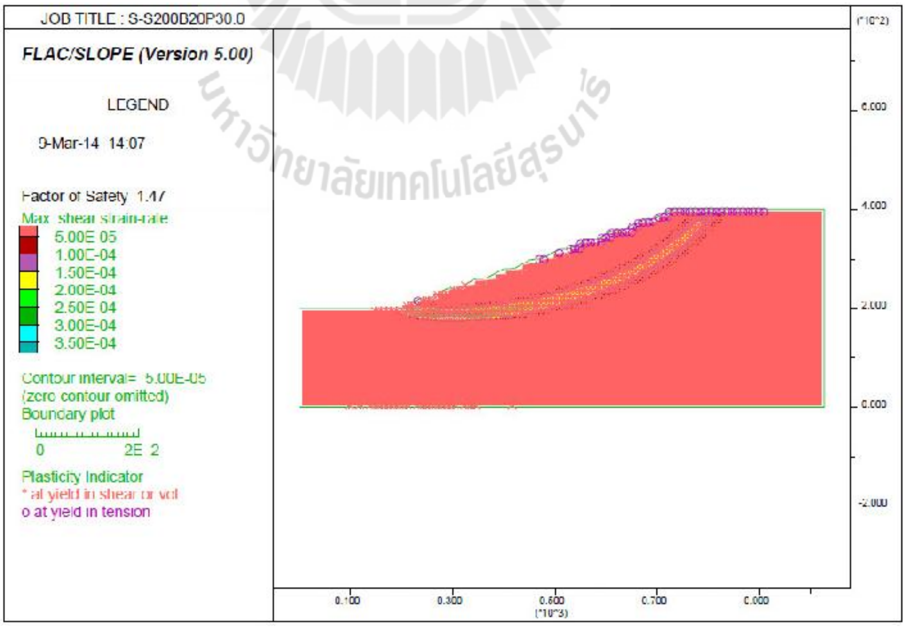
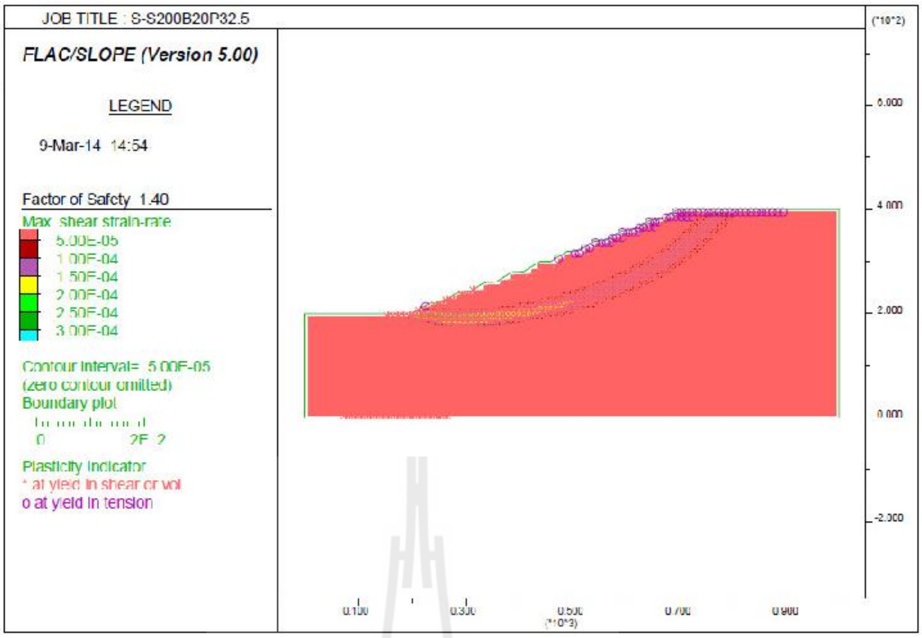
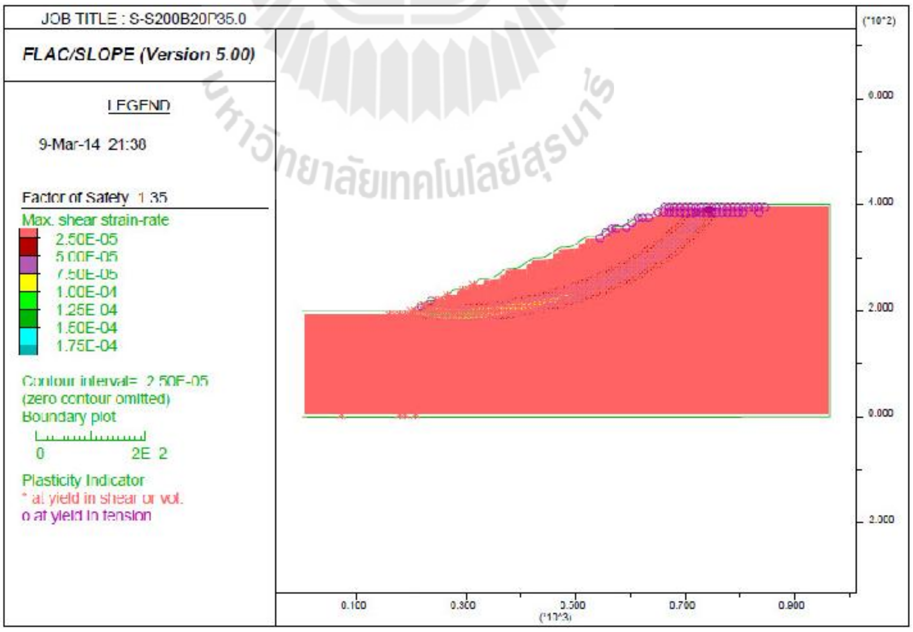
Factor of Safety 1.72
Max. shear strain-rate
2.50E-05
5.00E-05
7.50E-05
1.00E-04
1.25E-04
1.50E-04
1.75E-04
Contour interval= 2.50E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
7.000
5.000
3.000
1.000
-1.000
-3.000
0.100
0.300
0.500
0.700
0.900
1.100
(*10^3)

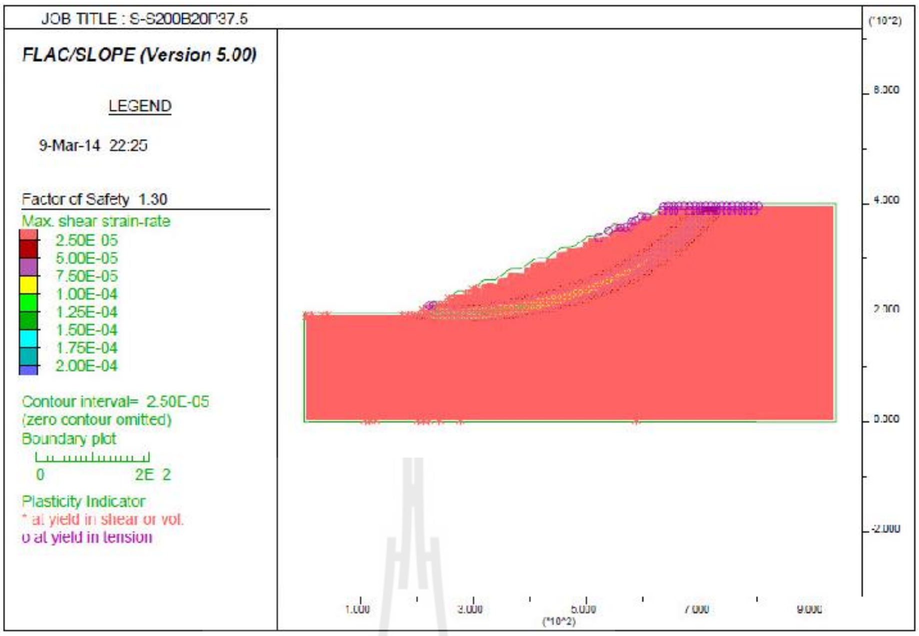

JOB TITLE : S-S200B20P25.0
FLAC/SLOPE (Version 5.00)
LEGEND
9-Mar-14 12:07
Factor of Safety 1.62
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
3.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
7.000
5.000
3.000
1.000
-1.000
-3.000
0.100
0.300
0.500
0.700
0.900
1.100
(*10^3)

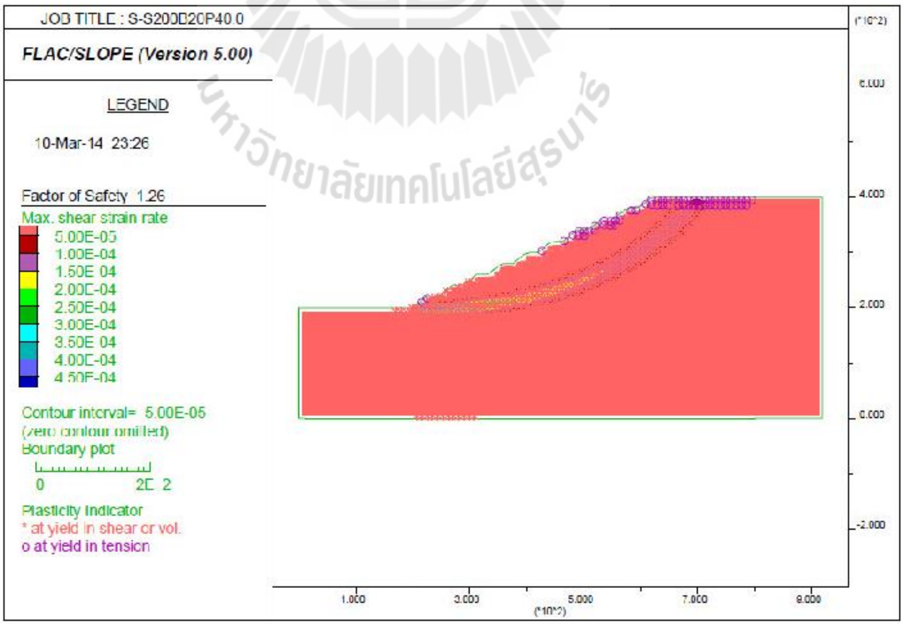

JOB TITLE : S-S200B20P27.5
FLAC/SLOPE (Version 5.00)
LEGEND
9-Mar-14 13:44
Factor of Safety 1.54
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
3.50E-04
4.00E-04
4.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension

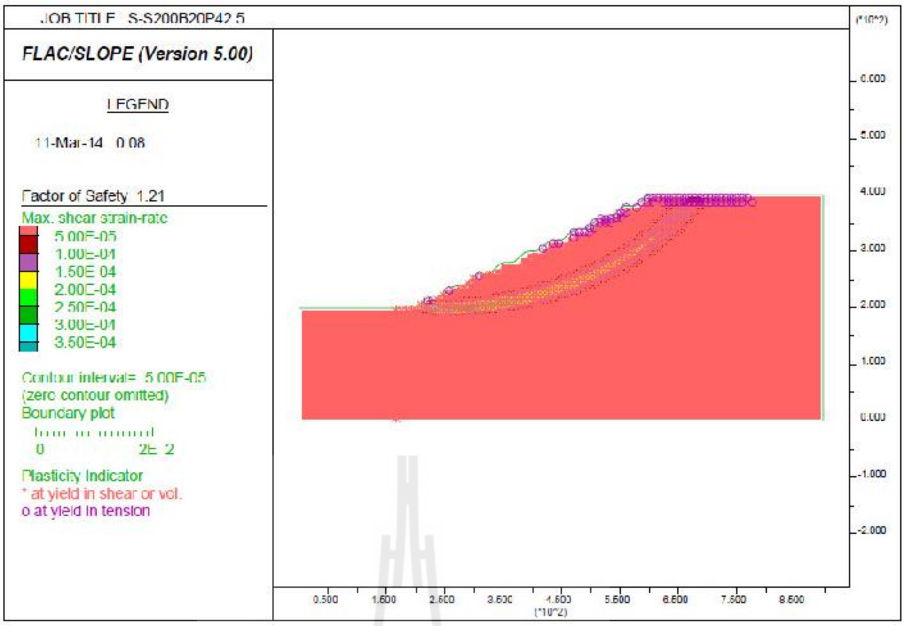

JOB TITLE : S-S200B20P30.0
FLAC/SLOPE (Version 5.00)
LEGEND
9-Mar-14 14:07
Factor of Safety 1.47
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
3.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol
o at yield in tension

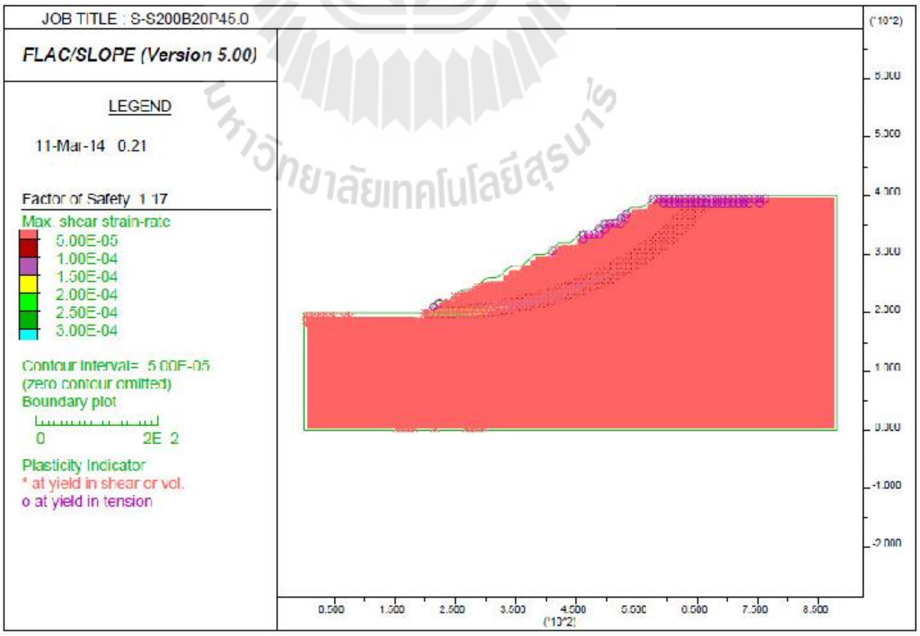

JOB TITLE : S-S200B20P32.5
FLAC/SLOPE (Version 5.00)
LEGEND
9-Mar-14 14:54
Factor of Safety 1.40
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol
o at yield in tension
(*10^2)
6.000
4.000
2.000
0.000
-2.000
0.100
0.300
0.500
0.700
0.900
(*10^3)

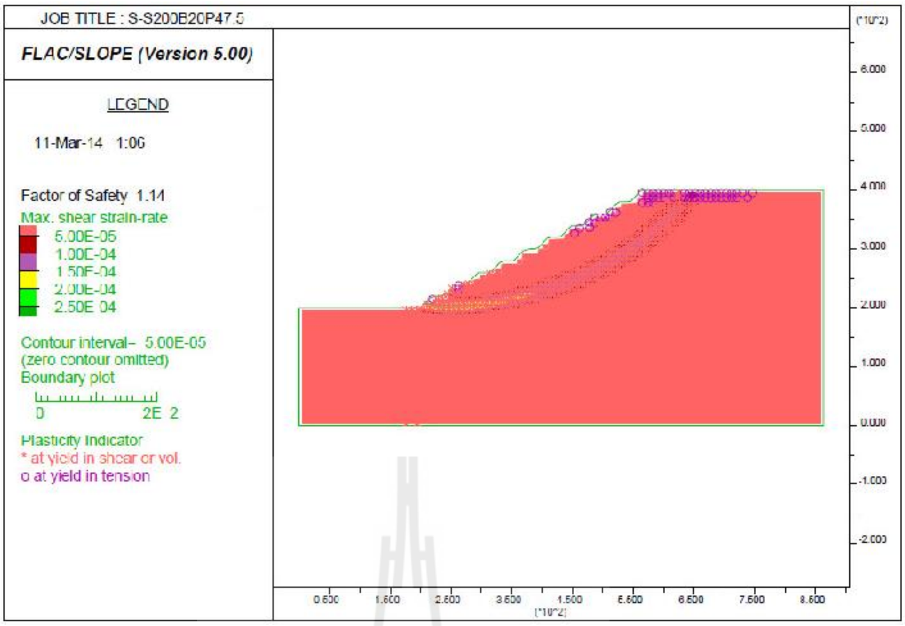

JOB TITLE : S-S200B20P35.0
FLAC/SLOPE (Version 5.00)
LEGEND
9-Mar-14 21:38
Factor of Safety 1.35
Max. shear strain-rate
2.50E-05
5.00E-05
7.50E-05
1.00E-04
1.25E-04
1.50E-04
1.75E-04
Contour interval= 2.50E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)
6.000
4.000
2.000
0.000
0.100
0.300
0.500
0.700
0.900

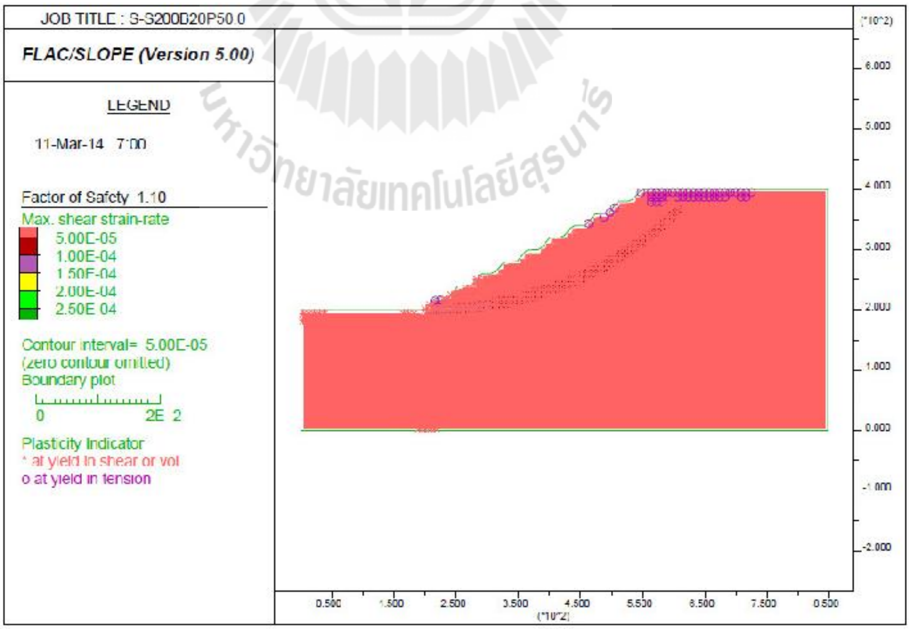

JOB TITLE : S-S200B20P37.5
FLAC/SLOPE (Version 5.00)
LEGEND
9-Mar-14 22:25
Factor of Safety 1.30
Max. shear strain-rate
2.50E-05
5.00E-05
7.50E-05
1.00E-04
1.25E-04
1.50E-04
1.75E-04
2.00E-04
Contour interval= 2.50E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension


JOB TITLE : S-S200B20P40.0
FLAC/SLOPE (Version 5.00)
LEGEND
10-Mar-14 23:26
Factor of Safety 1.26
Max. shear strain rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
3.50E-04
4.00E-04
4.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension


JOB TITLE : S-S200B20P42.5
FLAC/SLOPE (Version 5.00)
LEGEND
11-Mar-14 0:08
Factor of Safety 1.21
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
3.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)


JOB TITLE : S-S200B20P45.0
FLAC/SLOPE (Version 5.00)
LEGEND
11-Mar-14 0:21
Factor of Safety 1.17
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension
(*10^2)


JOB TITLE : S-S200B20P47.5
FLAC/SLOPE (Version 5.00)
LEGEND
11-Mar-14 1:06
Factor of Safety 1.14
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol.
o at yield in tension


JOB TITLE : S-S200B20P50.0
FLAC/SLOPE (Version 5.00)
LEGEND
11-Mar-14 7:00
Factor of Safety 1.10
Max. shear strain-rate
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
Contour interval= 5.00E-05
(zero contour omitted)
Boundary plot
0 2E 2
Plasticity Indicator
* at yield in shear or vol
o at yield in tension

BIOGRAPHY

Mr. Thongchai Boonklung was born on April 25, 1985 in Srakeaw province, Thailand. He received his Bachelor's Degree in Engineering (Civil Engineering) from Suranaree University of Technology in 2007. For his post-graduate, he continued to study with a Master's degree in the Civil Engineering, Institute of Engineering, Suranaree University of Technology.