資料-７　参考資料

７－１　協力対象地の選定経緯

ミャンマー国地方部農村インフラ開発計画

八千代エンジニヤリング㈱・日本工営㈱

協力対象地の選定経緯

(1) 協力対象とする村落・村の取り扱いについて

本調査の業務指示書においては、本無償資金協力による協力対象地として表 1 に示す 6 村が選定されている。

表 1　業務開始時の調査対象村落・村

State／Region (州／地域)	Township （タウンシップ）	Village Tract (村落)	Village (村)
チン州	Falam	Zarthwlor	- Pa Mum Chaung
	Tedim	Dolluang	- Zo Zang - Dolluang - Swang Dawh
エーヤワディー地域	Mawlamyinegyun	Sit Sali Htone	- Sit Sali Htone
	Bogale	Sa Bai Kone	- Sa Bai Kone

出所：調査団作成

表 1 の調査対象村落・村は、本件準備調査に先行して実施された「ミャンマー国貧困削減小規模インフラ情報収集・確認調査」（以下、「既往情報収集・確認調査」という）の調査結果に基づき選定されたものである。既往情報収集・確認調査では、①貧困農民層の存在状況と BHN（Basic Human Needs）の充足状況、及び②農業開発ポテンシャル層に重点をおいて協力対象候補地を挙げた上で、農業畜産灌漑省及び州・地域政府との協議を通じて提案されたものである。その結果、既往情報収集・確認調査においては、対象とする州・地域ごとに表 2 の通り選定経緯及び結果が整理されている。

表 2　既往情報収集・確認調査における調査対象地域の検討結果

州・地域	選定経緯及び結果
チン州	チン州においては、ADBによる道路・給水支援事業が実施中である。ミャンマー側との協議を通じ、チン州においてはADB道路・給水支援事業は同州南部地域を含め展開しており、先方要望として北部地域を重点的に選定して頂きたいとの要望を受けている。同要望を踏まえ、道路密度が低く、給水条件に問題がある北部地域の３タウンシップを調査対象地域として選定した。
エーヤワディー地域	エーヤワディー地域では、エーヤワディー川河口部の道路密度、安全な水アクセスに問題のあるタウンシップを中心として候補地域を絞り込んだ。さらに、ミャンマー側との協議を通じ、同地域北部に位置するHintada タウンシップにおいて複合インフラ整備による支援ニーズが高いとの要望を受け、調査の必要性を認めた。以上より、５タウンシップを調査対象として選定した。

出所：「ミャンマー国貧困削減小規模インフラ情報収集・確認調査」関連資料に基づき調査団作成

また、既往情報収集・確認調査では、表 2 の検討・協議結果を踏まえ、表 3 の通り調査対象地域を最終化している。

表 3　既往情報収集・確認調査における調査対象地域一覧表

State／Region （州／地域）	Township （タウンシップ）	Village Tract （村落）	Village （村）
チン州	Hakha	Rim Pi	Rim Pi
	Falam	Webula	Webula
			Kim Mon Chung
			Pa Mum Chaung
	Tedim	Dolluang	Zo Zang
			Dolluang
			Swang Dawh
エーヤワディー地域	Myaungmya	Moke Soe Kwin	Moke Soe Kwin
		Shan Yae Kyaw	Shan Yae Kyaw
	Labutta	Thin Gan Gyi	Thin Gan Gyi
		Laput Pyay Lae Pyauk	Lae Pyauk
	Hinthada	Tha Si	Thar Si Thu Gyi Su
	Mawlamyinegyun	Sit Sali Htone	Sit Sa Li Htone
	Bogale	Sa Bai Kone	Sa Bai Kone

出所：「ミャンマー国貧困削減小規模インフラ情報収集・確認調査」関連資料に基づき調査団作成

一方、本件協力準備調査における第一次現地調査の対処方針「(9) 広域的な視点」として、「必要に応じてある程度広域的な観点も念頭に置いたサイト選定やサブプロジェクトに留意する。」との方針付けがある。

本方針に関連し、調査団は、チン州とエーヤワディー地域の調査対象地域周辺の地域特性として、表 4 の通り把握している。

表 4　業務開始時の調査対象村落・村

調査対象地	地域特性
チン州	広大な面積を有する村落内に村が広域的に散在している。そのため、同一の村落内であっても、各村は山間部や平野部など異なる地理的条件下に位置しており、生活環境も大きく異なる。特に、山間部については、道路が未整備であるため村同士の相互アクセスは確保されていない。
エーヤワディー地域	狭小な村落内に村が集中している。そのため、村落内の各村は類似した生活環境下にある。また、道路事情は劣悪であるが、村同士が近接しているため相互アクセスは相対的に容易である。

出所：調査団作成

以上の対処方針及び地域特性を踏まえ、チン州及びエーヤワディー地域それぞれにおいて、事業実現性を踏まえた協力対象村落・村の最終案として表 5 の通り選定した。

表 5　協力対象村落・村の最終案

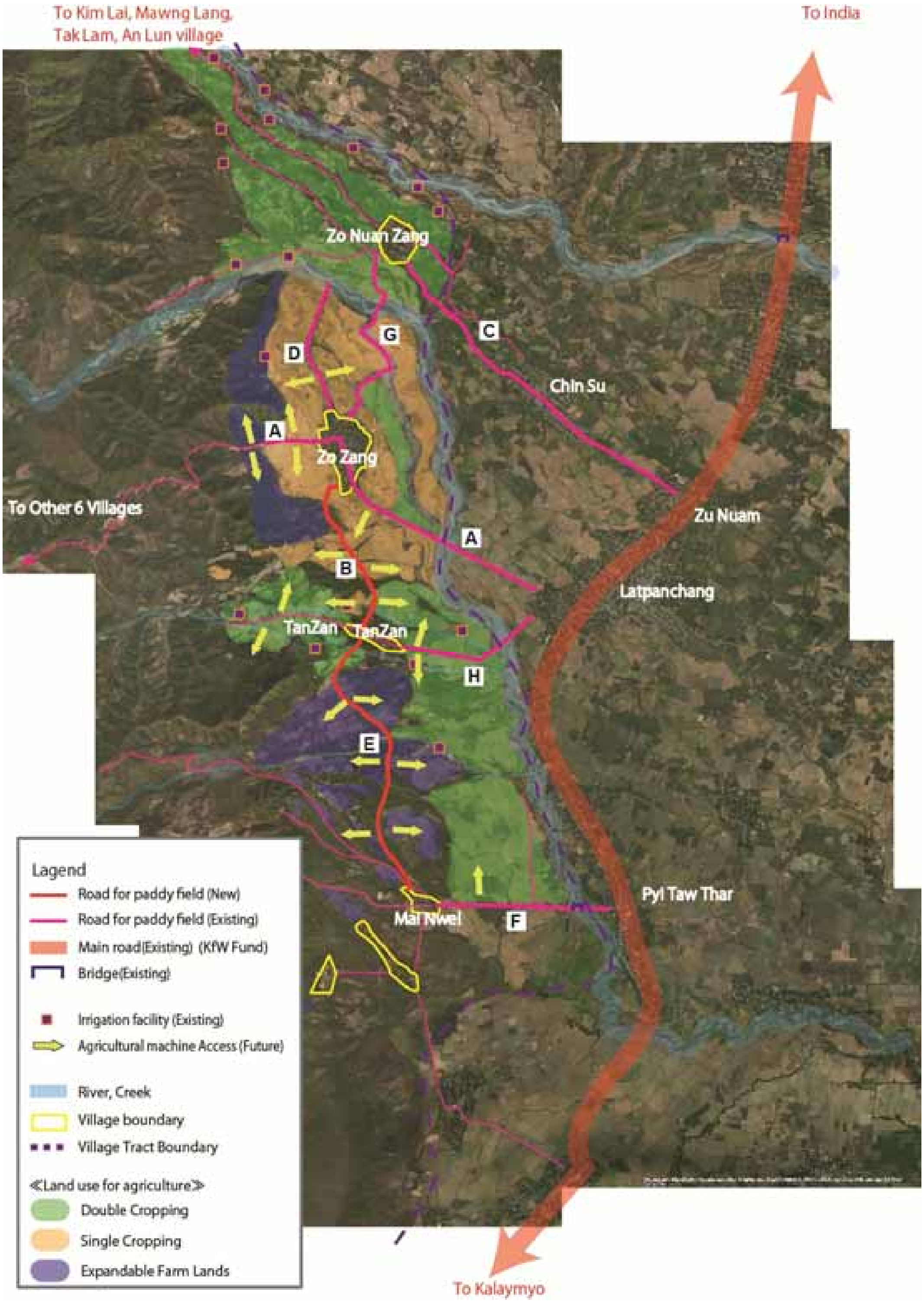
State／Region (州／地域)	Township (タウンシップ)	Village Tract (村落)	Village (村)
チン州	Falam	Zarthwlor	村落内の 2 村中 1 村 - Pa Mum Chaung
	Tedim	Dolluang	村落内の 10 村中 5 村注 1) - Zo Zang - Zo Nuan Zang - Tan Zan - Dolluang - Swang Dawh
エーヤワディー地域	Mawlamyinegyun	Sit Sali Htone	村落内の全 4 村 - Sit Sali Htone - Pat Taw - Ywar Ka Lay - Bon Taung Su
	Bogale 注 2)	Sa Bai Kone	村落内の全 8 村 - Sa Bai Kone - Ba Wa Thit - Ywar Tan Shay - Mote So Chaung - Sa Kar Lon Kone - Dar Chaung - Nga Pi Tone Hle - U Do Kan Su
		Tha Kan Wa	村落内の全 11 村 - Tha Kan Wa - Tha Kan - Kyaung Su - Hin Oh Gyi - Kyon Pha - Ngwe Taung - Da None - Aung Mingalar - Tae Pin (1) - Tae Pin (2) - Tae Pin (3)

注 1）Dolluang 村落の協力対象地は、本資料（2）において対象村の絞り込み提案を行う。
注 2）Bogale タウンシップの協力対象地は、本資料（3）において対象村落の絞り込み提案を行う。
出所：調査団作成

表 5 の欄外に示す通り、チン州 Tedim タウンシップ Dolluang 村落の協力対象地は、本資料(2)において対象村の絞り込み提案を行う。同様に、エーヤワディー地域 Bogale タウンシップの協力対象地については、本資料（3）において対象村落の絞り込み提案を行う。

(2) チン州 Zo Zang 村及び周辺地域の協力対象地検討について

当初調査対象である Zo Zang 村、ならびに周辺地域に検討対象を拡大した場合の事業効果について検証した。下図に示す路線「A」～「H」のうち、農村地域における開発効果の観点から「A」「B」「C」のインフラの優先度が高く、次いで「E」のインフラの優先度が高いと評価した。



出所：調査団作成

図 1　チン州 Zo Zang 村及び周辺地域のインフラ計画

表 6 に、上記の通り評価した検証根拠を示す。

表 6　Zo Zang 村及び周辺地域における候補路線の事業評価・事業実施時の裨益人口・事業効果

対象村名	図内番号	想定される道路・橋梁インフラ	生活向上			農業所得向上		農外所得向上	裨益人口	事業効果	優先度	事業費（百万円）
			マーケット	学校	医療施設	農業生産	市場アクセス					
Zo Zang	A	道路山中 6 村～ Zo Zang ～ Latpanchang 4.1km、 Bridge (1)160m	○		○	○	○	○	Zo Zang、Tan Zan、山中 6 村の住民 4,064 人	• DRRD の開発計画である”Core Rural Road Network(CRRN)”によると、本道路は村と地方幹線道路を結ぶ道路として優先的に整備することと位置付けられており、上位計画と合致する • この道路は、Zo Zang のみでなく、山間 6 村のカレーミョへのアクセス道路であり、生活向上、農業所得、農外所得向上の全ての観点からみて必要性が高い。 • 候補コンポーネントの中で事業による裨益人口が最も多い。	1	450
	B	道路 Zo Zang～ Tan Zan 2.2km、 Bridge (4)20m×4		○	○	○			Zo Zang、Tan Zan の住民 2,262 人	• 農地拡大による農業所得向上の観点からみて必要性が高い。 • 事業による裨益人口も比較的多い。 • 「Tan Zan 住民の学校・医療施設アクセス、村外交流など生活向上に必要な道路であり緊急度は高い。	1	170
	D	道路 Zo Zang 内（頭首工まで） 1.6km、 Bridge (2)15m,10m				○			主に Zo Zang の農業により所得を得ている世帯の住民約 1,815 人	• 農業機械の搬入が容易となり農業の効率化に貢献できる。 • 雨季に河川の増水に伴い、年間 3～5 回、用水路が決壊した水が本道路に流入し、路面が年々浸食している状況にある。そのため、道路及び排水を整備することにより、防災に大きく寄与する効果が期待できる。ただし、河川取水口の頭首工対策工事は本無償資金協力事業として扱うには規模が過大となる。そのため、流入する水量の管理が困難であることから、道路施設の破損など瑕疵責任の問題が懸念される。したがって、本路線は除外する。	—	—
	G	道路 Zo Zang～ Zo Nuan Zang 約 2.2km、 Bridge (1)				○			Zo Nuan Zang、Zo Zang の住民 2,468 人	• 農業機械の搬入が容易となり農業の効率化に貢献できる。 • 一方、橋梁工事は事業規模が大きく、過大投資になる。本路線は除外する。	—	—
Zo Zang を含む周辺	C	道路 Zo Nuan Zang ～ Latpanchang 3.7km、 Bridge (1)15m	○	○	○	○	○	○	Zo Nuan Zang、Zo Nuan Zang の北部 4 村の住民 1,520 人	• DRRD の開発計画である”Core Rural Road Network(CRRN)”によると、本道路は村と地方幹線道路を結ぶ道路として優先的に整備することと位置付けられており、上位計画と合致している。 • 生活圏・物流圏からみた必要性、農業所得向上、農外所得向上の全ての観点からみても必要性が高い。 • CRRN によると、本道路は「A」の道路と同様の準幹線道路の位置づけであり、裨益対象は、Zo Nuan Zang だけでなく、北部 4 村、Latpanchang に向かう道中の村にも広げることができる。	1	120

対象村名	図内番号	想定される道路・橋梁インフラ	生活向上			農業所得向上		農外所得向上	裨益人口	事業効果	優先度	事業費（百万円）
			マーケット	学校	医療施設	農業生産	市場アクセス					
										• ドルアン村落の平坦地域における均質な支援という観点からも、同地域一帯での事業効果が期待できる。		
	E	道路 Tan Zan～Mai Nwel 3.6km 、 Bridge (6) 20m×6				○			Tan Zan、Mai Nwel の住民 718 人	• 農業拡大の可能性のある土地があり、事業実施により作物の収量増加、所得向上が期待できる。 • 農業所得向上の観点から本路線の整備効果は認められる。一方、「B」の事業実施により、Tan Zan は「B」「A」によりザガイン地域側との通年交通が確保され、Mai Nwel についても「F」からザガイン地域側へのアクセス事情が比較的良好であることから、緊急度は優先度「1」の路線と比べると低い。	2	250
	F	道路 Mai Nwel ～Pyi Taw Thar 1.6km 、 Bridge (2) 7m×2	○		○	○		○	Mai Nwel の住民 418 人	• DRRD の開発計画である"Core Rural Road Network(CRRN)"によると、本道路は村と地方幹線道路を結ぶ道路として優先的に整備することと位置付けられており、上位計画と合致している。 • 既存道路は橋梁が架設されており、雨季にも村外とのアクセス確保されており、緊急度は低い。したがって、本路線の整備効果は低く、除外する。	—	—
	H	道路 Tan Zan ～ Latpanchang Bridge (1)	○		○	○		○	Tan Zan の住民 300 人	• Zo Zang にアクセスする路線「A」上の橋梁整備の優先度が高く、近接する本路線上で橋梁するには事業規模（橋長約 250m が大きく、裨益人口を勘案すると過大投資になる恐れがある。したがって、本路線の整備効果は低く、除外する。	—	—

出所：調査団作成

「A」「B」の道路整備を実施することにより、農業・農外所得向上が図れるとともに、年間を通じて主要な生活圏・物流圏となるカレーミョまでのアクセスが確保され、Zo Zang に加え Tan Zan、山中 6 村を含む 4,064 人が、事業の恩恵を受けることができる。

「C」の道路整備を実施することにより、事業対象となる Zo Nuan Zan だけでなく同村北部 4 村およびザガイン地域周辺の村の住民のアクセス向上にも貢献することができる。また、本路線を整備することにより、ドルアン村落の全 10 村のうち、平坦地に位置する全 4 村の域外への良好なアクセスが確保され、地方農村開発の平準化を図ることが可能となる。

「E」の道路整備は、農業拡大の可能性のある土地の農業開発とあわせて進めることにより、Tan Zan 及び Mai Nwel の農業により所得を得ている 66 世帯（400 人）の所得向上を期待できる。ただし、Mai Nwel とザガイン地域の Pyi Taw Thar 間は、比較的健全な既存橋梁を整備済みのため緊急度は低い。

一方、「D」「G」「F」「H」については、上表に示す理由から本事業による協力対象から除外することとしたい。

(3) エーヤワディー地域 Sa Bai Kone 村落南地域への協力対象拡大の可能性について

協力対象とするエーヤワディー地域 Sa Bai Kone 村落の南地域には、Hpa Yar Thone Su 村落が広がっている（図 2 参照）。対処方針「(9) 広域的な視点」の観点から、同 Hpa Yar Thone Su 村落への道路計画延伸について、事業効果、技術的課題、本邦企業型による実施などの視点から事業実現性を検討した。検討の結果、以下の理由により本計画対象地域から除外することとしたい。

- C 区間（図 2 参照）終点において灌漑局が整備したとされる既存道路と接続することにより、終点以南とのミッシングリンク解消が期待されていたが、C 区間終点での現地確認の結果、灌漑局道路は雨季の路面泥濘化により通行困難であることが判明した。そのため、対象 C 区間によるミッシングリンク解消は実現不可能と判断される。
- C 区間の既存道路は畦道程度の狭小幅員であり、標準道路幅員（6.0m）まで拡幅するためには盛土工事が必要となる。現地聞取り調査の結果、対象地域周辺では盛土の沈下収束に 1～3 年を要することから、長期にわたる工程、または沈下対策として事業費が過大となる。
- 工事箇所へのアクセスが困難であり、建設材料や重機の搬入が水運に限定される。そのため、施工計画が煩雑となり、本区間を対象とすることにより本邦企業の関心を低下させる。

出所：調査団作成

図 2　エーヤワディー地域 Sa Bai Kone 村落南地域

以　上

７－２　自然条件調査結果（チン州）

REPORT

ON

TOPOGRAPHIC SURVEY

AND

SOIL INVESTIGATION AT

CHIN STATE PROJECT

FALAM AND TEDIM TOWNSHIP, CHIN STATE

THE REPUBLIC OF THE UNION OF MYANMAR

JICA PROJECT TEAM

FKYB - SI –236/2017-023

FEBRUARY, 2018

Submitted by:
Fukken Co., Ltd. (Consulting Engineers)
www.myanmargeoconsultant.com

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1 INTRODUCTION

Geotechnical investigation is generally carried out to determine the substratum of ground (soil and rock) for small and large scale constructions, such as high-rise buildings, bridges, dams, factories, ports & jetties to be constructed and needs proper design of required structures. JICA PROJECT TEAM is planning to construct the bridges and other related structures at Falam and Tedim Township, Chin State. Therefore, Fukken Co., Ltd. was assigned to conduct soil investigation works to obtain soil properties of selected locations in the project area.

1.1 Objective of Project

The soil investigation conducted during this project phase intends to define the subsurface conditions at project site as much as possible to evaluate the requirements of designing the structure. The specific objectives envisage to-

1. To understand the distribution condition of stratum in this project area
2. To recognize the physical and mechanical properties of soil
3. To evaluate the appropriate soil design parameter for construction design process
4. To point out the hazardous effects of ground respond during and after construction

1.2 Scope of Work

The scope of investigation works include three portions; field investigation work, laboratory testing and report preparation. The field investigation work includes soil boring, soil undisturbed sampling and Standard Penetration Test (SPT). There are six boring points and the total depth of investigation for all boreholes is 122.77 meter in this project area. The depth of boreholes is in accordance with soil condition of the points selected by expert's direction, according to the client requirements. Standard penetration tests were performed in all boreholes of designated locations in complies with ASTM (American Society for Testing and Materials). The collected disturbed samples and undisturbed samples from the boreholes were analyzed at Fukken's Yangon Branch Laboratory.

(1) Field Works

Boring works by TOHO-D1 Drilling Machines.

- Standard Penetration Test
- Soil Disturbed Sampling

(2) Laboratory Test
- Physical properties test of soil
- Mechanical properties test of soil

(3) Reports

All the field investigation works and laboratory tests were carried out in accordance with ASTM, and the units are applied with SI.

1.3 Project Location

Project area is located at Falam and Tedim Township, Chin State. The detailed location of project area is indicated as a google map in Figure-1.1 and as a map as well in Figure-1.2.

Borehole Location for Letpanchaung Side

Borehole Location for Pamumchaung Side

Figure - 1.1 Google map of project area

1.4 Project Duration and Personnel

Fukken Co., Ltd. conducted field investigation work at the designated area of Falam and Tedim Township, Chin State. The field investigation works were started from 12th October, 2017 and completed all boreholes on 29th November, 2017. The laboratory tests were carried out after field work and completed on 10th January, 2018.

The executed detailed actual working schedule is illustrated in Table-1.1, indicating the organization chart of personnel of the operation, including list of geotechnical engineers, drilling crews for boring machines, technicians and the entire persons involved in this operation.

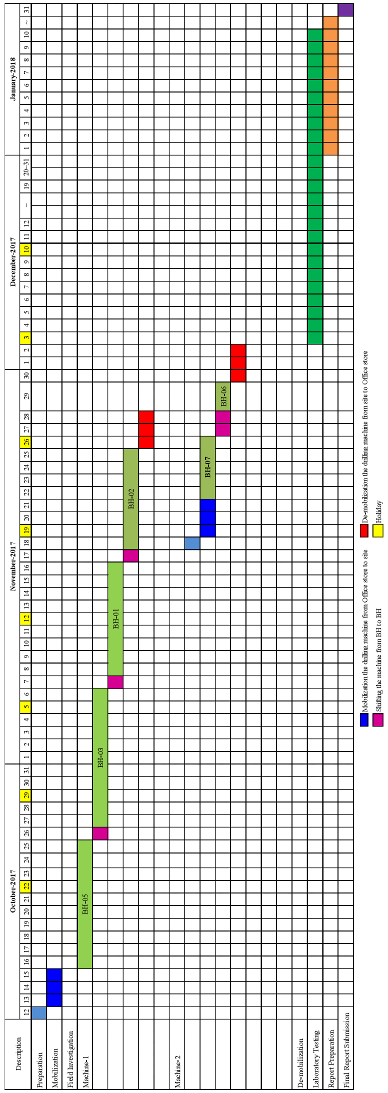
Photo - 1.1 Mobilization of Equipment

Photo - 1.2 Panoramic view of project area

Photo - 1.3 One of drilling condition

Photo - 1.4 Demobilization of Equipment

Table - 1.1 Actual Working Schedule of Geotechnical Investigation Works



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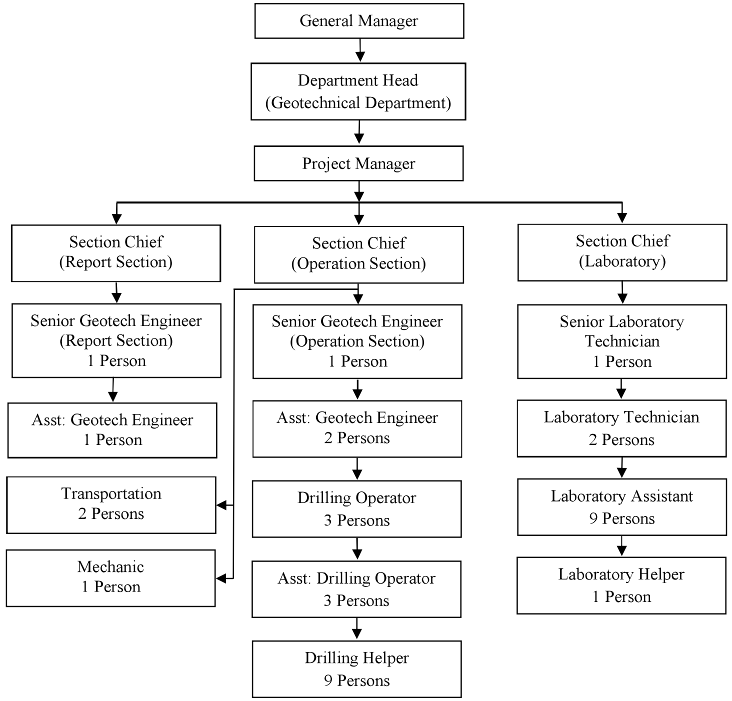

Figure - 1.2 Organization Chart of the works

1.5 Equipment Applied in the Project

1.5.1 Boring Equipment

The boring equipment, TOHO-D1 was applied in the soil investigation work of project area, to study general condition of soil layers under planned area for future construction. The specification and the types of boring equipment were presented in Table-1.2

Photo - 1.5 TOHO-D1 Drilling Machine

Table - 1.2 Specification of Boring Equipment

Parts of Equipment	Particulars
Brand of Boring machine	TOHO-“D1”
Boring Type	Rotary
Feeding Type	Hydraulic Feed Type
Drilling Capacity	150m
Spindle Stroke	400mm
Spindle Inner Dia.	43mm
Hoisting Speed	10~59m/min
Weight	476kgf
Oil Pump Delivery Capacity	19 l/min
Oil Pump Working Pressure	45~70kgf/cm^2
Attached Water Pump Type	Toho “BG-3B”
Discharge Capacity	54 l/min
Working Pressure	15 kgf/cm^2
Engine	Yanmar Engine 110
Power	11.0 HP

1.6 Laboratory Instruments

The principal instruments applied for soil laboratory tests are as shown in the following table.

Table - 1.3 Applied Laboratory Instruments

Instrument Name	Manufacturer and Type
Drying Oven	YF-STHX-3A
Electrical Balance	SARTORIUS 1404B (MP8-1)
Atterberg Limits Test Apparatus	MARUI 1115013
Sieve Test Equipment	TOKYO SAITAMA (JIS Z 8801)

Photo - 1.6 Drying Oven

Photo - 1.7 Electrical Balance

Photo - 1.8 Atterberg Limits Apparatus

Photo - 1.9 Sieve Test Equipment

Photo - 1.10 Pycnometer for Specific Gravity Test

2 SITE CHARACTERIZATION

In this chapter, it would be included about the topography, regional geologic setting and geology of the project area in Falam and Tedim Township, Chin State.

2.1 Topography

The project area is located in two different places and can be divided into two groups. The first group located in Falam Township and the second group located in Tedim Township respectively, in Chin State. The topography of first group, located, somewhere around BH-5, BH-6 and BH-7 in Falam Township, is surrounded by steep slopes and hilly region. Boreholes were carried out on the bank of chaung (creeks).

The second group located in Tedim Township and the topography of the area, in general, somewhere around BH-1, BH-2 and BH-3, is flat low lying land.

Photo - 2.1 View of Project Area

2.2 Regional Geologic Setting

According to the Geology of Burma (Myanmar) (Dr. F Bender, 1983), from West to East, Burma can be divided into four major physiographic units, mentioned here under, which run more or less N-s and which are bounded in the northernmost part of the country by a fifth unit striking approximately W-E, namely the E Himalayas.

- The Arakan (Rakhine) Coastal Area
- The Indo-Burma Ranges
- The Chindwin-Irrawaddy Basin, or Inner Burman Tertiary Basin
- The Sino-Burman Ranges

The central section of the Indo-Burman Ranges bends towards the south with the Chin Hills and reaches altitudes up to more than 3,000 m (MT. Victoria 3,201 m). In the South section of the Indo-Burman Ranges, the Arakan (Rakhine) Yoma (Padaung, 1,390 m), the height of the mountains declines as they strike SSE down to the Andaman Sea.

Refer to the geological map of Burma, the project sites and surrounding areas are lied on the northern part of Indo-Burman Ranges. In this area, the sediments are of Cretaceous. The overburden soil layer of the project site is Holocene Alluvium (Q2). By boring results of soil investigation, the project area is made up of alluvial deposit of CLAY, Clayey SAND and Silty SAND. According to the geological map, the regional geological setting of the stratigraphic succession of project area is as follow-

Description	Symbols	Age
Alluvium	Q2	Holocene
Globotrucana-bearing Flych	K	CRETACEOUS
Units of Western Ranges and Orbitolina-bearing Limestones of Northern Burma		

2.3 Earthquake Intensity of Myanmar

Geographically, a large part of Myanmar lies in the southern part of the Himalayas and the eastern margin of the Indian. Due to this situation the country is exposed to the hazards of large earthquakes. Earthquakes in Myanmar have resulted from two main causes: (1) the continued subduction (with collision only in the north) of the northward-moving Indian plate underneath the Burma Platelet (which is a part of the Eurasian Plate) at an average rate of 4.5cm/yr; and (2) the northward movement of the Burma Platelet from a spreading center in the Andaman Sea at an average rate of 2.5 -3.0 cm/yr (Bertrand et al., 1998; Curray, 2005). Very large overthrusts along the Western Fold Belt have resulted from the former movement, and the Sagaing and related faults from the latter movement. Intermittent jerks along these major active faults have caused ther majority of earthquakes in Myanmar. These seismotectonic processes are still going on (Dr. Maung Thein and U Soe Thura Tun, April 2009).

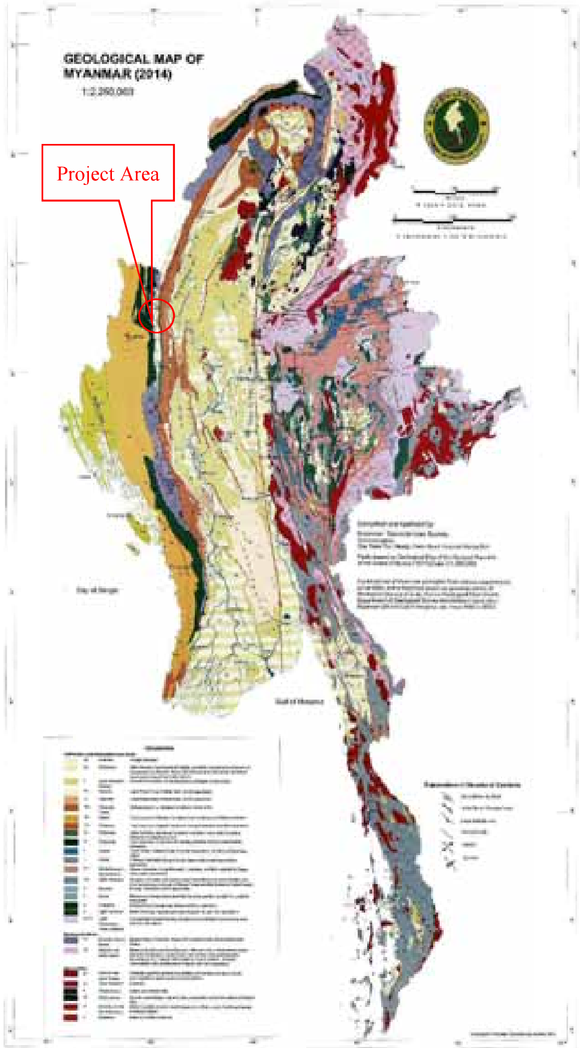

Figure - 2.1 Geological Map of Project Area

3 FIELD INVESTIGATION

3.1 Investigation works

The objective of the present investigation is to identify the general stratification of the ground and the nature of the soil. Total six boring points were planned to investigate by the client's requirements. The field investigation included soil boring with the performing of the test associated with Standard Penetration Test (SPT), Disturbed Soil Sampling, Undisturbed Soil Sampling, Water Level Measuring and Water Sampling. Total boring length is 122.77m and the total quantity of investigation work is listed in Table-3.1.

Table - 3.1 Total Quantity of Boring Works

No.	BH. No.	Soil Drilling (m)					Standard Penetration Test (Nos)	Undisturbed Sampling (Nos)	Coring sampling (Nos)	Water Sample (Nos)
		Ø 112 mm	Ø 90 mm	Ø 64 mm	Coring	Total				
1	BH-01	5.0	15.0	15.42	-	35.42	35	-	-	1
2	BH-02	5.0	7.5	12.68	-	25.18	25	-	-	1
3	BH-03	4.0	1.0	20.17	-	25.17	25	1	-	1
4	BH-05	-	10.0	3.0	2.0	15.0	13	-	2	1
5	BH-06	-	-	-	6.0	6.0	1	-	5	1
6	BH-07	1.0	-	9.0	6.0	16.0	8	-	6	1
Total		**15.0**	**33.5**	**60.3**		**122.77**	**107**	**1**	**13**	**6**

3.2 Location of Boring Points

The locations of investigated points were designated by client. The plan map showing geotechnical investigated points are indicated in Figure-3.1. The coordinate and elevation of all borehole points are shown in Table-3.2. The coordinate of all investigated points were measured by Total Station equipment and the elevations of all investigated points were measured by Auto level from Control Point (CP-03) which is locating at near Letpanchaung Village. Photo-3.1 is shown the leveling process and Control Point (CP-03).

Photo - 3.1 Leveling Process and Control Point (CP-03)

Figure - 3.1 Location of Investigated Points

Table - 3.2 Coordinates and Boring Ponts

No.	BH No.	Easting (E)	Northing (N)	Elevation EL: (m)
1	BH-01	602838.000	2581018.000	+134.4
2	BH-02	602766.000	2581052.000	+134.6
3	BH-03	602708.000	2581081.000	+135.36
4	BH-05	599480.551	2541655.085	+306.14
5	BH-06	598998.000	2541730.000	+298.47
6	BH-07	597688.000	2542462.000	+391.00
7	CP-03	601605.539	2581358.842	+147.412

Photographs showing location of boring points

Photo - 3.2 View of BH-01

Photo - 3.3 View of BH-02

Photo - 3.4 View of BH-03

Photo - 3.5 View of BH-05

Photo - 3.6 View of BH-06

Photo - 3.7 View of BH-07

3.3 Boring Works

In boring, rotary direct circulation method is appropriately applied using metal crown bits attached to casings of Ø112mm, Ø90mm and metal crown bits of Ø64mm in diameter setting with single core tube are properly applied depending on soil condition to drilling process. The drilling machines are operated by setting on the stage with maintaining horizontal level of drilling machine and vertical position of drilling direction while drilling on field investigation works. Boring and SPT testing in all the points are operated from drilling stage maintaining the stability of boring machine. In the way of direct circulation of drilling fluid, water and bentonite slurry was inevitably utilized to control the circulation of the sludge. The schematic diagram of boring equipment is shown in following Figure - 3.2.

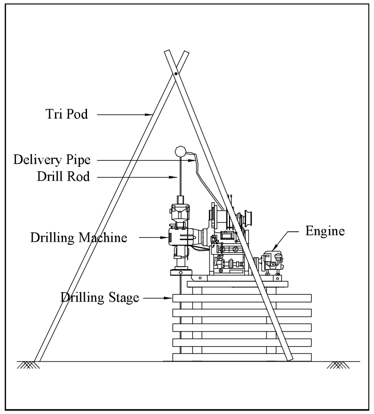

Figure - 3.2 Schematic View of Drilling Machine setting

3.4 Standard Penetration Test (SPT)

The standard penetration test was done in accordance with the ASTM Standard (American Society for Testing and Materials; D 1586-99). The test was performed using a spilt barrel sampler (50mm diameter) connected to the end of boring rods. The sampler was driven into the soil by means of a 63.5kg (140lb) hammer falling freely through the height of 76cm onto the anvil attached to the rod. The sampler is driven 450mm into the soil. SPT N-value is recorded for each 150mm penetration of the sampling tube. In this case, seating drive of 150mm is first reached and the blow count for the seating drive is not applied because the bottom of the hole may be apart from natural condition at a certain extent. The resistance, N-value, is taken as number of blow for the penetration of test drive of next 300mm. When 50 blows are reached before the full penetration 300mm, no other blows are applied but final penetration is recorded. At the conclusion of the test, the retained soil sample is extracted and stored in plastic bag for further analysis. In which, Figure-3.3 indicates the procedure and apparatus of standard penetration test. The distribution of N-value for each stratum is summarized in Figure-3.4 and Figure-3.5.

Photo - 3.8 View of Standard Penetration Test and SPT Sample

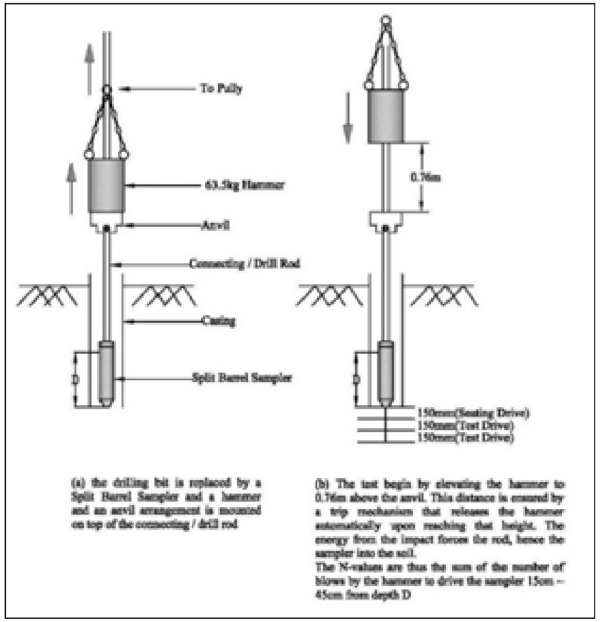

Figure - 3.3 Procedure and Apparatus of Standard Penetration Test

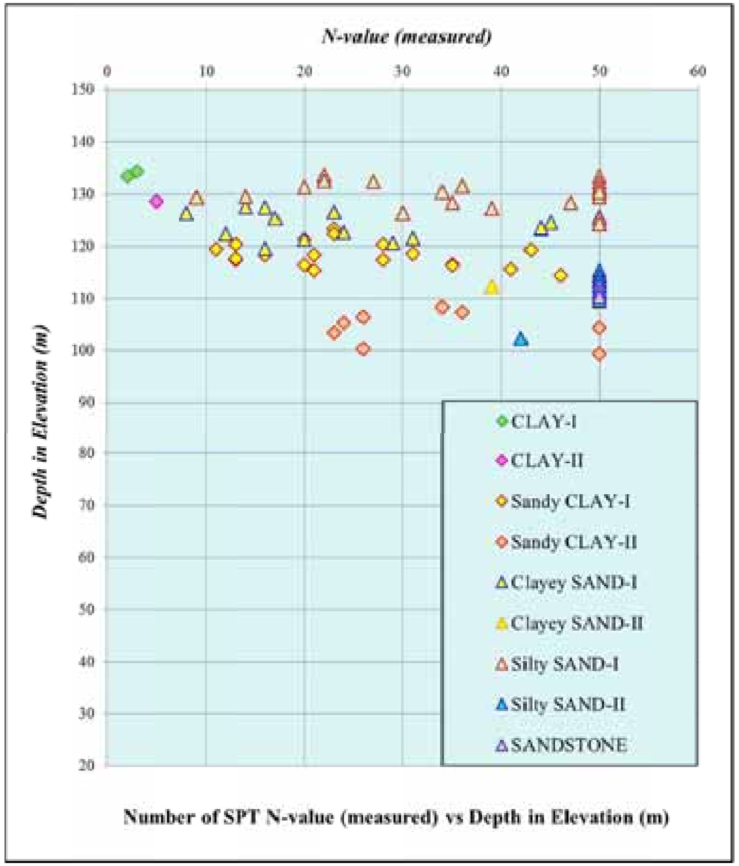

Figure - 3.4 Number of N-Value (measured) vs Depth in Elevation (m) for BH-01, BH-02 and BH-03 (Letpan Side)

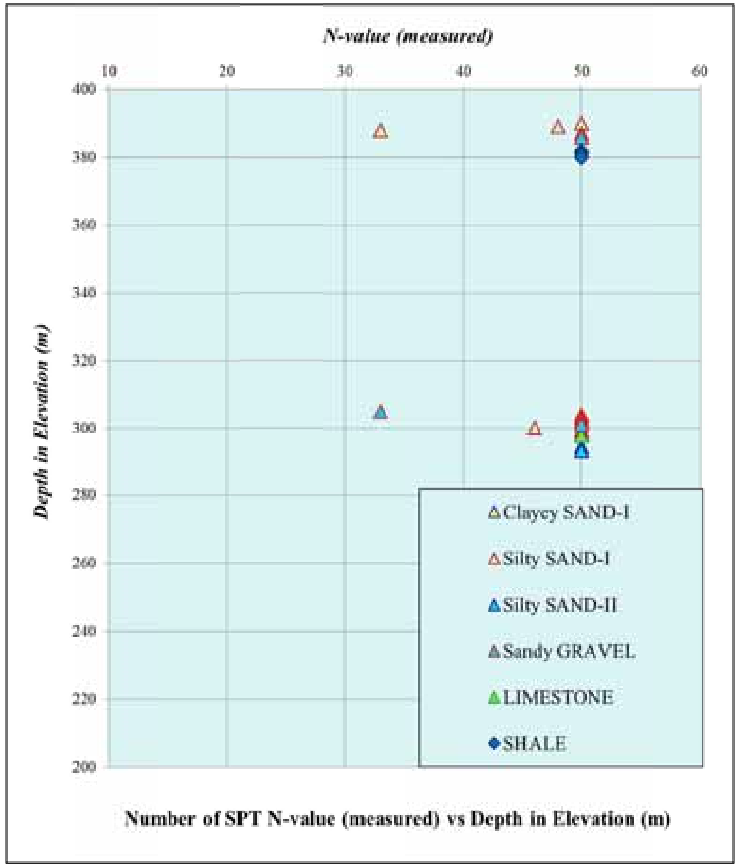

Figure - 3.5 Number of N-Value (measured) vs Depth in Elevation (m) for BH-05, BH-06 and BH-07 (Pamumchaung Side)

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Falam and Tedim Township, Chin State

3.5 Characteristics of Soil Strata Relying on Field Test

There are six numbers of boreholes, the depth of boreholes is a minimum 6.0m and a maximum 35.42m from ground level with the performance of Standard Penetration Test and rock core sampling. In this operation, total nine numbers of different layers for BH-01, BH-02 and BH-03(Letpanchaung Side) and total eight numbers of different layers for BH-05, BH-06 and BH-07(Pamumchaung Side) have been recognized. The soil layers are classified in accordance with their physical properties and their relative density (or) Consistency. The different layers observed in project area are described as follows.

Soil layer for Letpanchaung side

BH-01, BH-02 and BH-03

5. CLAY-I
6. CLAY-II
7. Sandy CLAY-I
8. Sandy CLAY-II
9. Clayey SAND-I
10. Clayey SAND-I
11. Silty SAND-I
12. Silty SAND
13. SANDSTONE(Rock)

Soil layer for Pamumchaung side

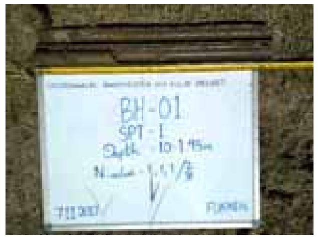
BH-05, Bh-06 and BH-07

1. Clayey SAND-I
2. Silty SAND-I
3. Silty SAND-II
4. Sandy GRAVEL
5. LIMESTONE(Rock)
6. SHALE(Weathered Soil)
7. SANDSTONE(Rock)

Soil layer for Letpanchaung side (BH-01, BH-02 and BH-03)

3.5.1 CLAY-I

According to the investigation results, the upper most layer is CLAY-I layer. The thickness of this layer is maximum 2.0m. The color of this layer is yellowish brown. The plasticity of this layer is low to medium plasticity and the water content is moist. Moreover, trace of fine lateritic gravel is including in this layer. SPT N-value range of this layer is 2/30 to 3/30 blows, and it can be described as very soft to soft in consistency.

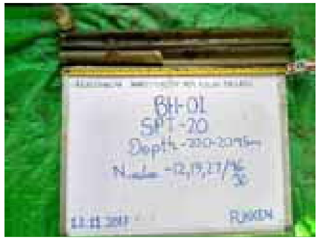


3.5.2 CLAY-II

This layer is observed at BH-02, and the name of this layer is CLAY-II. The thickness of it is a maximum 1.00m. The color of it is yellowish brown, and the water content is moist at that depth. The plasticity of this layer is low to medium plasticity. SPT N-value range is 5/30 blows, and it can be described as firm in consistency description.

3.5.3 Sandy CLAY-I

This layer is observed at BH-01, BH-02 and BH-03. The thickness of this layer is a minimum 4.0m and a maximum 8.0m. The color of this layer is yellowish brown and brownish gray. The plasticity of this layer is low to high plasticity and the water content is moist. Moreover, trace of fine lateritic gravel is including in this layer. SPT N-value range of this layer is 11/30 to 50/25 blows, and it can be described as stiff to hard in consistency.

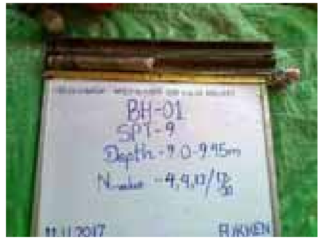


3.5.4 Sandy CLAY-II

This layer is observed in BH-01, and the name of this layer is Sandy CLAY-II. The thickness of it is a maximum 6.00m. The color of it is yellowish brown, and the water content is moist water content. The grained size of sand is fine grained. SPT N-value range is from 26/30 to 50/27 blows, and it can be described as very stiff to hard in consistency.

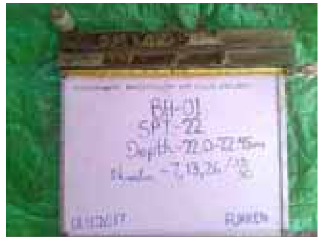
3.5.5 Clayey SAND-I

This layer is Clayey SAND-I and this layer is well observed only at BH-01 and BH-02. The thickness of this layer is a minimum 7.0m and a maximum 9.0m. The color of this layer is yellowish brown to dark gray and the water content is moist. The grained size of sand is fine to coarse grained and the plasticity of clay is low to medium plasticity. SPT N-value range is 8/30 to over 50 blows. The relative density of it is loose to very dense.



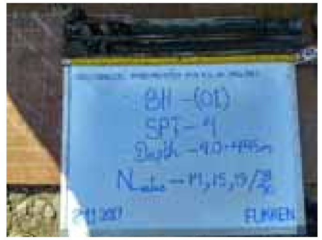
3.5.6 Clayey SAND-II

This layer is only observed at BH-01. The thickness of this layer is about 4.0m. The color of this layer is brownish gray. The plasticity of this layer is low plasticity and the water content is moist. Moreover, trace of gravel and rock fragment is including in this layer. SPT N-value range of this layer is 39/30 to 50/12 blows, and it can be described as dense to very dense in relative density.



3.5.7 Silty SAND-I

This layer is well observed at all three boreholes. The thickness of this layer is a minimum 5.0m and a maximum 10.0m. The color of this layer is yellowish brown and brownish gray. The plasticity of this layer is low and the water content is moist. Moreover, trace of rock fragment is including in this layer. SPT N-value range of this layer is 9/30 to over 50 blows, and it can be described as loose to very dense in relative density.



3.5.8 Silty SAND-II

Silty SAND-II layer is also well observed in all the three boreholes. The thickness of this layer is about 2.0m at BH-01 and BH-03. But , at the BH-02 the thickness of this layer is cannot be estimated because the BH-02 is terminated in this layer The color of this layer is yellowish brown to dark gray and the water content is moist. The grained size of sand is fine to coarse grained and the plasticity of clay is low to medium plasticity. SPT N-value range is 15/30 to 50/3 blows. The relative density of it is loose to very dense.

Soil layer for Letpanchaung side (BH-05, BH-06 and BH-07)

3.5.9 Clayey SAND-I

According to the investigation results, this Clayey SAND-I observed only at BH-05. The thickness of this layer is about 3.0m. The color of this layer is dark gray. The grained size of sand is fine to medium grained. The plasticity of this layer is low plasticity and the water content is moist. Moreover, trace of fine gravel is including in this layer. SPT N-value of this layer is over 50 blows, and it can be described very dense in relative density.

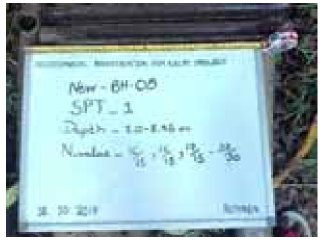
3.5.10 Silty SAND-I

This layer is observed at BH-05 and BH-07, and the name of this layer is Silty SAND-II. The thickness of it is a minimum 3.0m and a maximum 4.0m. The color of it is gray and the water content is moist. The grained size of sand is fine to medium grained. Moreover, trace of rock fragments including in this layer. SPT N-value range is 33/30 to over 50 blows, and it can be described as dense to very dense in relative density.

3.5.11 Silty SAND-II

This layer is observed only at BH-05. The thickness of this layer is about 2.0m. The color of this layer is dark gray. The grained size of sand is fine to medium grained. The plasticity of this layer is low plasticity and the water content is moist. Moreover, trace of fine lgravel is including in this layer. SPT N-value of this layer is over 50 blows, and it can be described as very dense in relative density.

3.5.12 Sandy GRAVEL



This layer is observed at BH-05 and BH-07. The thickness of this layer is a minimum 2.0m and a maximum 6m. The color of this layer is gray to dark gray. The water content is moist. Moreover, trace of weathered rock fragment is including in this layer. SPT N-value range of this layer is 33/30 to 50/2 blows, and it can be described as dense to very dense in relative density.

3.5.13 SANDSTONE

This layer is only observed at BH-05. The thickness of this layer is about 1.84m. The color of this layer is gray to dark gray. Strength is moderately strong and weathered SANDSTONE layer.

3.5.14 LIMESTONE

This layer is only observed at BH-06. The thickness of this layer is about 6.00M. The color of this layer is gray and strength is weak and moderately weathered LIMESTONE layer.

3.5.15 SHALE (Weathered Soil)

This layer is only observed at BH-07. The thickness of this layer is about 10.00M. The color of this layer is dark gray and strength is moderately strong and completely to moderately weathered SHALE layer.

According to the investigation results, soil profiles were drawn based on not only visual check of soil samples at site and SPT results of the boreholes but also laboratory test results to determine the cross section throughout project area. Figure-3.6 show the soil profile through the project area for Letpanchaung Side and Figure-3.7 to Figure-3.9 shows the soil profile for the project area for Pamumchaung Side.

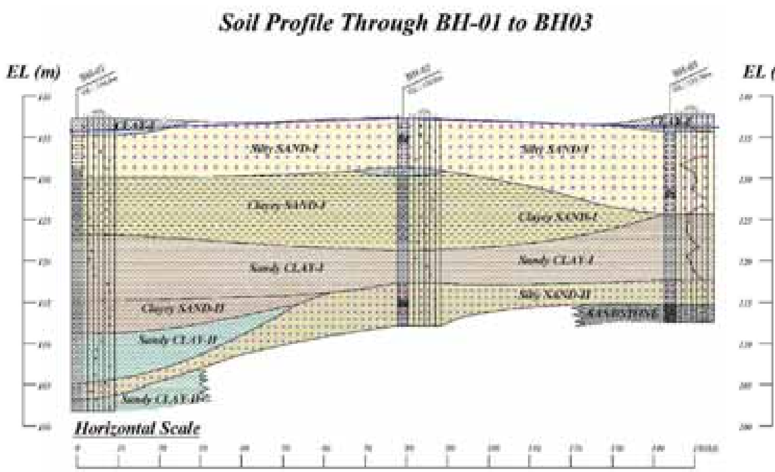


Figure - 3.6 Soil profile through the project area for Letpanchaung Side

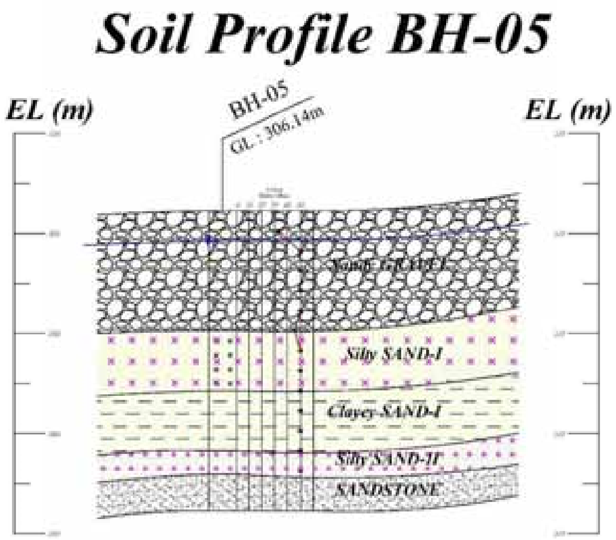


Figure - 3.7 Soil profile for BH-05 (Pamumchaung Side)

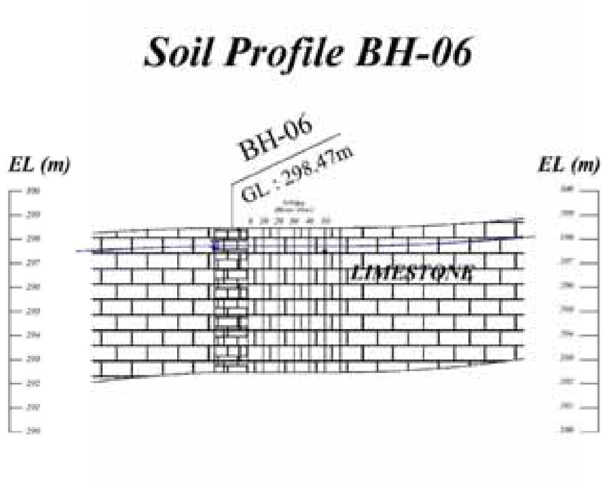


Figure - 3.8 Soil profile for BH-06 (Pamumchaung Side)

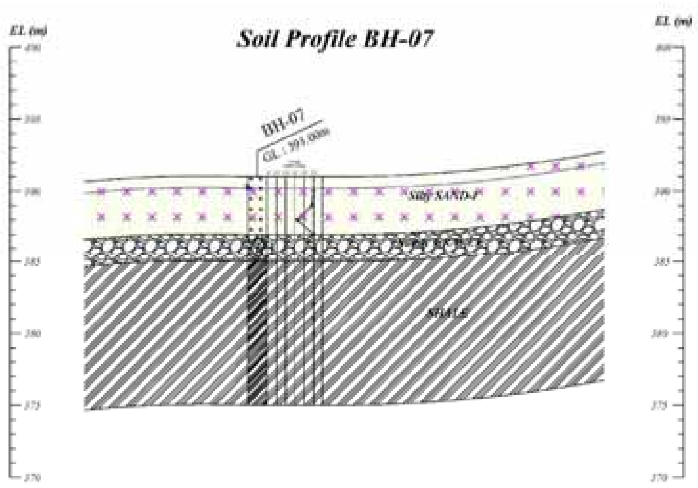


Figure - 3.9 Soil profile for BH-07 (Pamumchaung Side)

4 LABORATORY TEST

There have been six numbers of investigation boreholes and total (107) numbers of disturbed samples were collected in project site. Some selected numbers of disturbed samples were sent to office laboratory and purposed to test physical and mechanical properties of soil in consulting with expert's discretion. The entire tests were carried out in accordance with ASTM Standard.

The physical properties tests include the following items.

- Natural Moisture Content Test (ASTM D 2216-05)
- Specific Gravity Test (ASTM D 854-06)
- Particle Size Analysis Test (ASTM D 422-63)
  - Grain Size Distribution Test
  - Hydrometer Test

14. Atterberg Limits Test (ASTM D 4318-05)
  - Liquid Limit Test
  - Plastic Limit Test

Total quantity of laboratory tests are described in Table-4.1 and summary of laboratory test results for each borehole are illustrated in Table-4.2.

Table - 4.1 Total Quantity of Laboratory Tests

BH-No.	Physical Properties Test					
	Natural Moisture Content Test	Specific Gravity Test	Particle Size Analysis Test		Atterberg Limits Test	
			Sieve Analysis Test	Hydrometer Analysis Test	Liquid Limit Test	Plastic Limit Test
BH-N01	10	10	10	10	6	6
BH-N02	10	10	10	10	3	3
BH-N03	5	5	5	5	3	3
BH-N05	4	2	4	2	1	1
BH-N06	0	0	0	0	0	0
BH-N07	3	2	3	2	0	0
Total	**32**	**29**	**32**	**29**	**13**	**13**

Table - 4.2 Summary of Laboratory Test Results

BH No.	Sample No.	Depth GL - (m)	Depth EL; (m)	Soil Types	Water Content W (%)	Specific Gravity Gs	Grain Size Distribution Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Atterberg Limits LL (%)	PL (%)	PI (%)
BH-01	P-3	3.00	131.40	SM (or) SC	10.58	2.720	39.84	41.72	10.55	7.90	-	-	-
	P-7	7.00	127.40	SM (or) SC	25.00	2.749	26.85	33.30	21.86	18.00	-	-	-
	P-9	9.00	125.40	SM (or) SC	21.81	2.827	18.01	40.29	17.50	24.20	-	-	-
	P-12	12.00	122.40	SC	24.26	2.783	10.73	40.75	25.22	23.30	45.10	24.98	20.12
	P-15	15.00	119.40	CL	34.51	2.743	-	10.23	55.58	34.20	45.90	23.27	22.63
	P-19	19.00	115.40	CL	25.82	2.718	-	6.97	37.83	55.20	46.75	20.01	26.74
	P-22	22.00	112.40	SC	19.01	2.711	6.73	72.59	9.68	11.00	26.25	18.23	8.02
	P-29	29.00	105.40	CL	19.42	2.729	0.13	44.77	29.10	26.00	35.65	19.35	16.30
	P-32	32.00	102.40	SM (or) SC	20.01	2.771	28.76	49.27	10.38	11.60	-	-	-
	P-34	34.00	100.40	CL	18.27	2.720	-	27.03	46.98	26.00	29.30	16.93	12.37
BH-02	P-2	2.00	132.60	GP-GM (or) GP-GC	6.46	2.708	49.09	43.89	5.62	1.40	-	-	-
	P-5	5.00	129.60	SP	6.20	2.784	38.96	56.43	0.62	4.00	-	-	-
	P-6	6.00	128.60	CH	34.74	2.798	15.95	8.48	32.37	43.20	51.25	27.52	23.73
	P-8	8.00	126.60	SM (or) SC	17.52	2.784	35.15	36.65	13.70	14.50	-	-	-
	P-12	12.00	122.60	SM (or) SC	23.61	2.760	33.56	47.90	10.35	8.20	-	-	-
	P-15	15.00	119.60	SM (or) SC	29.43	2.752	11.25	74.62	8.13	6.00	-	-	-
	P-17	17.00	117.60	CL	30.13	2.725	1.48	6.64	34.68	57.20	45.95	22.59	23.36
	P-19	19.00	115.60	CL	18.70	2.704	-	18.90	41.90	39.20	32.40	16.84	15.56
	P-21	21.00	113.60	SM (or) SC	10.13	2.700	32.80	51.42	8.48	7.30	-	-	-
	P-24	24.00	110.60	SM (or) SC	8.17	2.695	30.87	42.77	20.16	6.20	-	-	-
BH-03	P-1	1.00	134.36	CL	27.11	2.678	-	25.40	49.60	25.00	33.70	20.30	13.40
	P-9	9.00	126.36	GM (or) GC	9.53	2.693	45.67	35.41	8.91	10.00	-	-	-
	P-14	14.00	121.36	CL	29.84	2.725	-	16.33	56.88	26.80	39.30	21.23	18.07
	P-18	18.00	117.36	CL	18.56	2.711	-	24.28	37.73	38.00	38.10	19.00	19.10
	P-21	21.00	114.36	SM (or) SC	6.35	2.734	31.85	47.79	9.56	10.80	-	-	-
BH-05	P-2	2.00	304.14	GP-GM(or)GP-GC	1.44	-	66.90	24.65	8.45		-	-	-
	P-5	5.00	301.14	GP-GM(or)GP-GC	1.79	-	51.47	38.78	9.75		-	-	-
	P-6	6.00	300.14	SM (or) SC	5.27	2.703	20.53	47.17	22.10	10.20	-	-	-
	P-10	10.00	296.14	SC	15.51	2.720	3.56	78.62	12.62	5.20	21.85	13.38	8.47
BH-07	P-3	3.00	388.00	SM (or) SC	6.76	2.754	22.43	63.45	10.52	3.60	-	-	-
	P-4	4.00	387.00	GP-GM(or)GP-GC	0.47	-	71.31	22.69	6.00		-	-	-
	P-7	10.00	381.00	SM (or) SC	4.01	2.773	19.37	65.09	10.94	4.60	-	-	-

4.1 Index Property of Soil

Physical and mechanical properties tests were done for investigation. The detailed laboratory test results are illustrated in Appendix-C in this report.

4.1.1 Natural Moisture Content Test

Natural moisture content tests of (32) numbers have been carried out on soil samples for required nine different soil layers at office laboratory in accordance with ASTM Standard (ASTM D 2216-05). Table-4.3 illustrates the summary of natural moisture content in each soil layers. The photograph of testing natural moisture content is shown in Photo-4.1 and the variation of moisture content with depth in elevation can be seen in Figure-4.1 and Figure-4.2. The detailed laboratory test results are illustrated in Appendix-C.

Photo - 4.1 Natural Moisture Content Test

Table - 4.3 Summary of Natural Moisture Content of Test Results

No.	Soil Types	Natural Moisture Content (%)
BH-01, BH-02 and BH-03 (Letpanchaung Side)		
1	CLAY-I	27.11
2	CLAY-II	34.74
3	Sandy CLAY-I	18.56 ~ 34.51
4	Sandy CLAY-II	18.27 ~ 19.42
5	Clayey SAND-I	17.52 ~ 29.43
6	Clayey SAND-II	19.01
7	Silty SAND-I	6.20 ~ 10.58
8	Silty SAND-II	6.35 ~ 20.01
BH-05, BH-06 and BH-07 (Pamumchaung Side)		
1	Clayey SAND-I	15.51
2	Silty SAND-I	5.27 ~ 6.76
3	Sandy GRAVEl	0.47 ~ 1.79
4	SHALE(weathered soilI	4.01

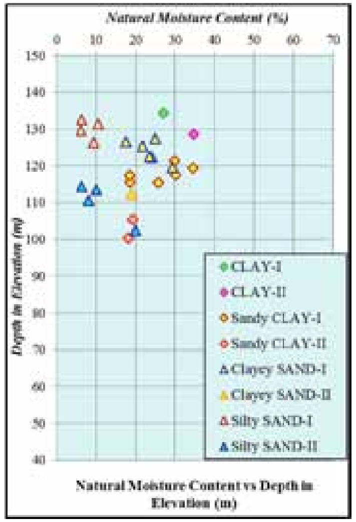


Figure - 4.1 Natural Moisture Content vs Depth in elevation (m) for Letpanchaung Side

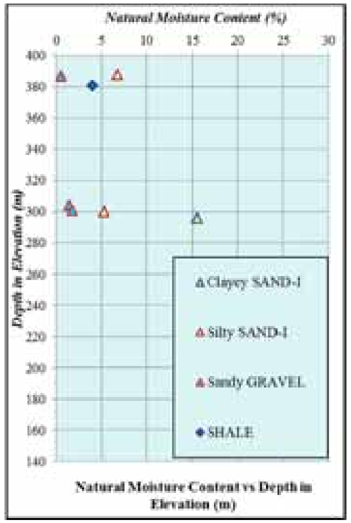


Figure - 4.2 Natural Moisture Content vs Depth in elevation (m) for Pamumchaung Side

4.1.2 Specific Gravity Test

The specific gravity tests in this project were carried out in accordance with ASTM Standard (ASTM D 854-06) at office laboratory. There have been (29) numbers of specific gravity tests. Table-4.4 illustrates the summary of specific gravity for each soil layer. The photograph of specific gravity testing is shown in Photo-4.2 and the relationship between specific gravity and depth in elevation of each soil layer is shown in Figure-4.3 and Figure-4.4. The detailed test results were described in Appendix-C.

Photo - 4.2 Specific Gravity Test

Table - 4.4 Summary of Specific Gravity Test Results

No.	Soil Types	Specific Gravity
BH-01, BH-02 and BH-03 (Letpanchaung Side)		
1	CLAY-I	2.678
2	CLAY-II	2.798
3	Sandy CLAY-I	2.704 ~ 2.743
4	Sandy CLAY-II	2.720 ~ 2.729
5	Clayey SAND-I	2.749 ~ 2.827
6	Clayey SAND-II	2.711
7	Silty SAND-I	2.693 ~ 2.784
8	Silty SAND-II	2.695 ~ 2.771
BH-05, BH-06 and BH-07 (Pamumchaung Side)		
1	Clayey SAND-I	2.720
2	Silty SAND-I	2.703 ~ 2.754
3	SHALE(weathered soill)	2.773

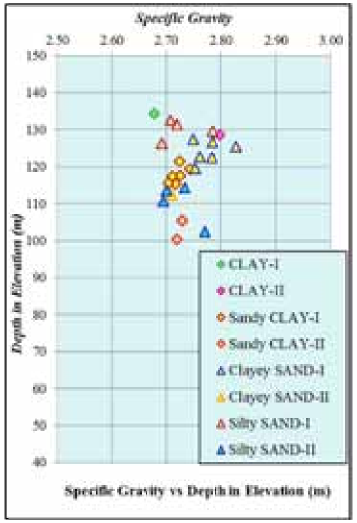


Figure - 4.3 Specific Gravity vs Depth in Elevation (m) for Letpanchaung Side

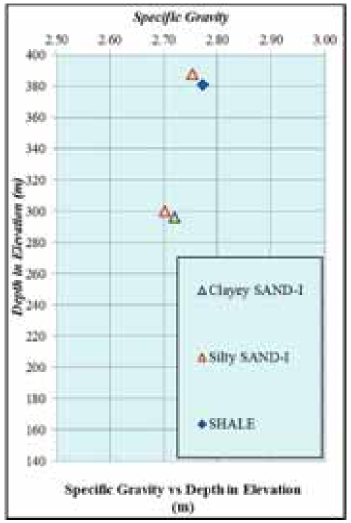


Figure - 4.4 Specific Gravity vs Depth in Elevation (m) for Pamumchaung Side

4.1.3 Atterberg Limits Test

The Atterberg Limits tests were made on (13) numbers for liquid limit tests and same numbers for plastic limit tests of specimens from disturbed samples by ASTM Standard (ASTM D 4318-05) at office laboratory. The summary of Atterberg Limits Test results are shown in Table-4.5. Figure-4.5 to 4.7 illustrate the Plastic Limit, Liquid Limit and Plasticity Index of each soil layer versus depth in elevation(m) for Letpanchaung Side and Figure-4.8 to Figure-4.10 illustrate the Plastic Limit, Liquid Limit and Plasticity Index of each soil layer versus depth in elevation(m) for Pamumchaung Side. Figure-4.11 shows condition of soil in project area by ranges in plasticity chart for Letpanchaung Side. The photograph of testing is shown in Photo-4.3. The detailed test results were shown in Appendix-C.

Photo - 4.3 Atterberg Limits Test (Liquid Limit & Plastic Limit)

Table - 4.5 Summary of Atterberg Limits Test Results

No.	Soil Types	Liquid Limit (LL) (%)	Plastic Limit (PL) (%)	Plasticity Index (PI)
BH-01, BH-02 and BH-03 (Letpanchaung Side)				
1	CLAY-I	33.70	20.30	13.40
2	CLAY-II	51.25	27.52	23.73
3	Sandy CLAY-I	32.40 ~ 46.75	16.84 ~ 23.27	15.56 ~ 26.74
4	Sandy CLAY-II	29.30 ~ 35.65	16.93 ~ 19.35	12.37 ~ 16.30
5	Clayey SAND-I	45.10	24.98	20.12
6	Clayey SAND-II	26.25	18.23	8.02
BH-05, BH-06 and BH-07 (Pamumchaung Side)				
1	Sandy CLAY-I	21.85	13.38	8.47

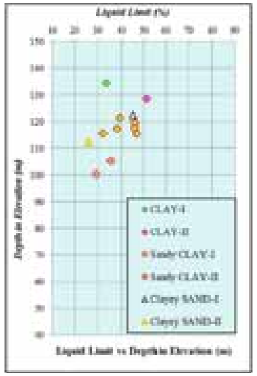


Figure - 4.5 Liquid Limit vs Depth in elevation (m) for Letpanchaung Side

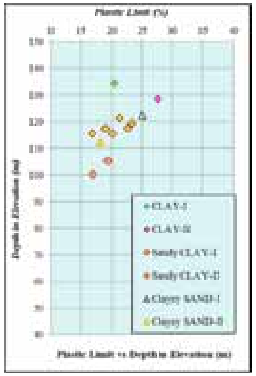


Figure - 4.6 Plastic Limit vs Depth in elevation (m) for Letpanchaung Side

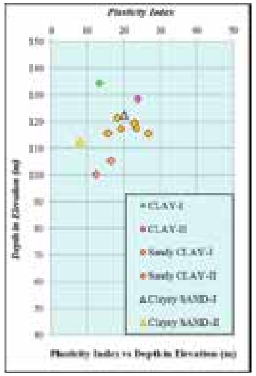


Figure - 4.7 Plasticity Index vs Depth in elevation (m) for Letpanchaung Side

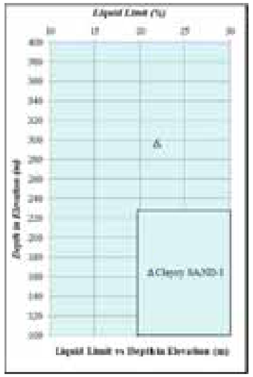


Figure - 4.8 Liquid Limit vs Depth in elevation (m) for Pamumchaung Side

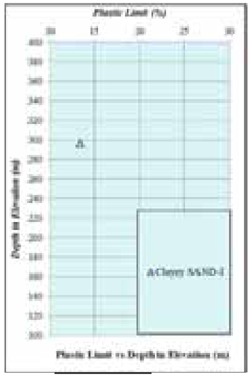


Figure - 4.9 Plastic Limit vs Depth in elevation (m) for Pamumchaung Side

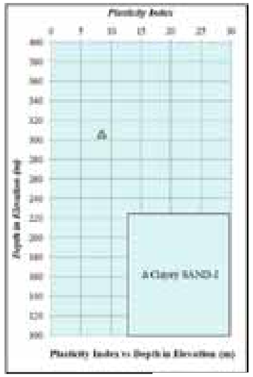


Figure - 4.10 Plasticity Index vs Depth in elevation (m) for Pamumchaung Side

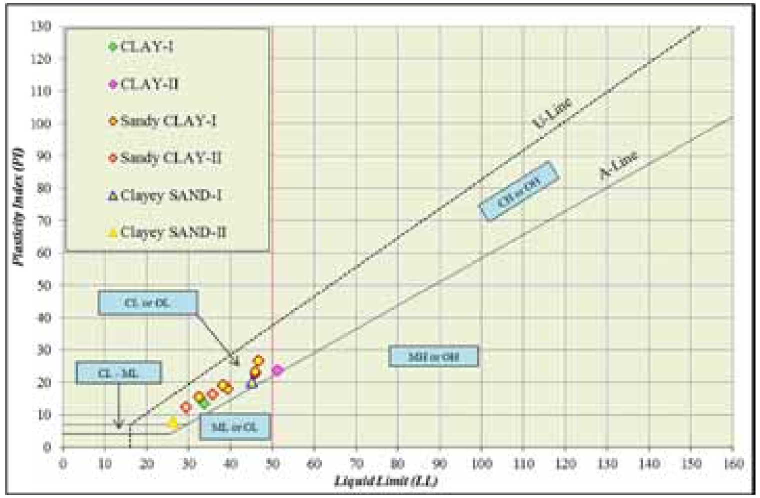


Figure - 4.11 Condition of Atterberg Limits Test Results for Letpanchaung Side

4.1.4 Grain Size Analysis Test

Soil classifications or grain size distribution test were done by ASTM Standard (ASTM D 422-63). In this project, (32) numbers of sieve analysis tests including (29) numbers of hydrometer tests were carried out in laboratory of Fukken Co., Ltd. Grain size analysis testing and hydrometer testing are shown in Photo-4.4 and 4.5. Figure-4.12 is illustrated the grain size distribution of each soil layer versus depth in elevation for Letpanchaung Side and Figure-4.13 is illustrated the grain size distribution of each soil layer versus depth in elevation for Pamumchaung Side. The details of Grain Size Analysis Test results were shown in Appendix-C.

Photo - 4.4 Grain Size Distribution Test

Photo - 4.5 Hydrometer Test

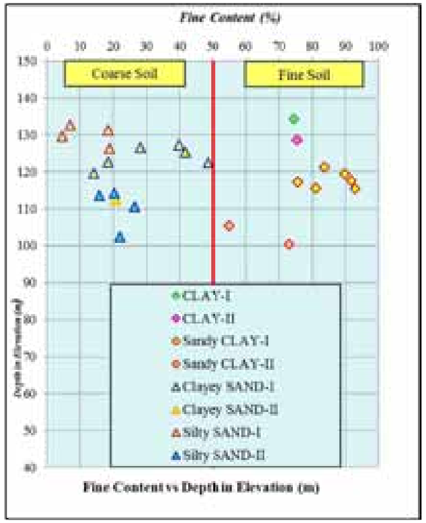


Figure - 4.12 Fine Content vs Depth in Elevation (m) for Letpanchaung Side

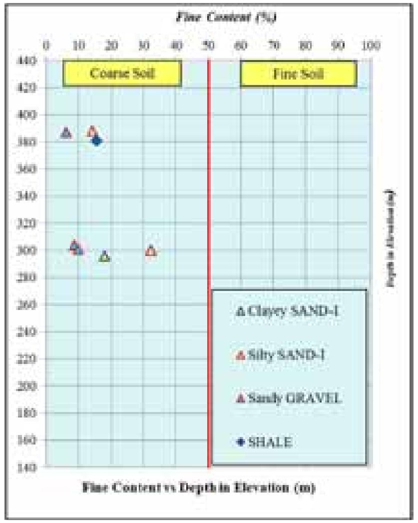


Figure - 4.13 Fine Content vs Depth in Elevation (m) for Pamumchaung Side

4.1.5 Design CBR Test

Design CBR Test was carried out in accordance with JIS Standard (JIS A 1211). Total (21) number of samples were performed in Kalay area. The location maps and coordinates of sampling points are shown in Figure-4.14 to Figure-4.16 and Table-4.6. Moreover, the photographs of each sampling point are indicated in Photo-4.6 to Photo-4.16.

Figure - 4.14 Sampling Point of CBR Test (Road-1)

Figure - 4.15 Sampling Point of CBR Test (Road-2, Road-3, Road-5and Road-6))

Figure - 4.16 Sampling Point of CBR Test (Road-7)

Table - 4.6 Coordinate of Sampling Point

Sr.	Road No.	Point No.	Easting	Northing
1	Road1	Point 1	599267.980	2541643.310
2	Road2	Point 2	603152.610	2580844.130
3		Point 3	602575.100	2581147.470
4	Road3	Point 1	601848.910	2581762.670
5	Road5	Point 1	601467.210	2582159.000
6	Road6	Point 2	601647.670	2581756.190
7		Point 3	601633.960	2581691.170
8		Point 4	601631.650	2581609.010
9	Road7	Point 2	604431.380	2582135.170
10		Point 3	603423.820	2582950.340
11		Point 4	602886.640	2583605.840

Soil samples were collected beside planned road points. Because, the existing road material was used beside a soil. Moreover, it was considered that road condition became the bad road due to the sampling.


Photo - 4.6 Sampling Point (Road 1, Point 1)


Photo - 4.7 Sampling Point (Road 2, Point 2)


Photo - 4.8 Sampling Point (Road 2, Point 3)


Photo - 4.9 Sampling Point (Road 3, Point 1)


Photo - 4.10 Sampling Point (Road 5, Point 1)


Photo - 4.11 Sampling Point (Road 6, Point 2)


Photo - 4.12 Sampling Point (Road 6, Point 3)


Photo - 4.13 Sampling Point (Road 6, Point 4)


Photo - 4.14 Sampling Point (Road 7, Point 2)


Photo - 4.15 Sampling Point (Road 7, Point 3)


Photo - 4.16 Sampling Point (Road 2, Point 3)

The photographs of each stage of Design CBR Test are shown in Photo-4.17 to Photo-4.19.

The summary table of results of Design CBR Test is indicated in Table-4.7. The details of Design CBR Test results were shown in Appendix-C.


Photo - 4.17 Compaction Stage


Photo - 4.18 Soaking Stage


Photo - 4.19 Penetration Stage

Table - 4.7 Summary of Design CBR Test Result

Road No.	Sampling Point	Sample No.	Result of Design CBR Test (%)		
			Specimen 1	Specimen 2	Mean CBR
Road 1	Point 1	1-2	23.9	24.4	24.2
		2-2	25.2	17.9	21.6
Road 2	Point 2	1-2	5.8	5.8	5.8
		2-2	7.0	7.7	7.4
	Point 3	1-2	0.3	0.3	0.3
		2-2	0.2	0.3	0.3
Road 3	Point 1	1-2	7.9	10.5	9.2
		2-2	9.2	10.0	9.6
Road 5	Point 1	1-2	57.1	58.0	57.6
		2-2	40.0	34.3	37.1
Road 6	Point 2	1-2	2.6	2.4	2.5
		2-2	5.7	6.3	6.0
	Point 3	1-2	4.8	5.4	5.2
		2-2	3.4	3.2	3.3
	Point 4	1-2	27.7	34.4	31.0
		2-2	31.7	33.5	32.6
Road 7	Point 2	1-2	9.4	9.8	9.6
		2-2	8.5	8.0	8.3
	Point 3	1-2	0.5	0.5	0.5
		2-2	0.4	0.4	0.4
	Point 4	1-2	4.2	4.0	4.1

5 GEOTECHNICAL ASSESEMENT

5.1 Setting of geotechnical design parameters

The geotechnical parameters are set up by the results of field testing and laboratory testing. Some of the design parameters cannot be evaluated directly neither from field tests nor laboratory tests due to the unfavorable nature of deposits or investigation methods. However, some parameters can be evaluated from the reference formulas by using SPT N-values, and sometimes referred from standard of Nippon Expressway Company Limited (hereinafter called "NEXCO").

(1) Unit weight of soil (γ_t)

Unit weight of soil (γ_t) can be obtained from laboratory test as Bulk density in case of taking undisturbed sample. For the case of non-taking undisturbed sample, unit weight of soil (γ_t) is referred to Table-5.1. Moreover, unit weight of soil (γ_t) can be evaluated from the following formula.-

$\gamma_t = (G_s\gamma_w (1 + w) / (1 + e)$ --- *Braja M. Das, Principles of Foundation Engineering Seventh Edition*

(2) Saturated unit weight of soil (γ_{sat})

Saturated unit weight of soil (γ_{sat}) can be obtained from laboratory test as Bulk density in case of taking undisturbed sample. For the case of non-taking undisturbed sample, saturated weight of soil (γ_{sat}) is referred to Table-5.1 and also can be evaluated from the following formula.-

$\gamma_{sat} = (G_s\gamma_w + e\gamma_w) / (1 + e)$ --- *Braja M. Das, Principles of Foundation Engineering Seventh Edition*

Where- γ_{sat} = saturated unit weight of soil (kN/m^3)

γ_w = unit weight of water (kN/m^3)

G_s = specific gravity of soil

w = water content

e = void ratio of soil ($e = wG_s$ for saturated clayey soil)

Remarks; *This formula can be used only under groundwater level and clayey soil.*
G_s and w can be obtained from laboratory tests results of collected "Disturbed Samples".

(3) Effective unit weight of soil (γ')

The effective unit weight of soil under water table can be evaluated from the equation-

$\gamma' = \gamma_t - \gamma_w$ for Clay/Silt --------- Japanese Code

$\gamma' = \gamma_t - 9.0$ for Sand/Gravel --------- Japanese Code

Where-

γ' = effective unit weight of soil (kN/m^3)

γ_w = unit weight of water (kN/m^3)

Table - 5.1 Recommended Soil Parameter by NEXCO*

Soil Type		Condition of Soil		Bulk Density γt (tf/m³)	Internal Friction Angle φ (°)	Cohesion Cu (tf/m²)	Remarks (Soil Name)
Fill Material	Gravel Gravelly Sand	Compacted one.		2.0	40	0	(GW), (GP)
	Sand	Compacted one.	Well graded one.	2.0	35	0	(SW), (SP)
			Poor graded one.	1.9	30	0	
	Silty Sand Clayey Sand	Compacted one.		1.9	25	Less than 3	(SM), (SC)
	Silt, Clay	Compacted one.		1.8	15	Less than 5	(ML), (CL) (MH), (CH)
	Kanto Loam	Compacted one.		1.4	20	Less than 1	(VH)
Natural Ground	Gravel	Dense or Well graded one.		2.0	40	0	(GW), (GP)
		Not dense and Poorly graded one.		1.8	35	0	
	Gravelly Sand	Dense one.		2.1	40	0	(GW), (GP)
		Not dense one.		1.9	35	0	
	Sand	Dense or Well graded one.		2.0	35	0	(SW), (SP)
		Not dense and Poorly graded one.		1.8	30	0	
	Silty Sand Clayey Sand	Dense one.		1.9	30	Less than 3	(SM), (SC)
		Not dense one.		1.7	25	0	
	Sandy Silt Sandy Clay	Stiff one.		1.8	25	Less than 5	(ML), (CL)
		Firm one.		1.7	20	Less than 3	
		Soft one.		1.6	15	Less than 1.5	
	Silt Clay	Stiff one.		1.7	20	Less than 5	(CH), (MH), (ML)
		Firm one.		1.6	15	Less than 3	
		Soft one.		1.4	10	Less than 1.5	
	Kanto Loam	—		1.4	5	Less than 3	(VH)

: Reference value of Silty SAND-I, II, Clayey SAND-I, II and Sandy CLAY-I, II and CLAY-I, II

*Nippon Expressway Company Limited

(4) Cohesion strength (c)

The cohesive strength, also known as undrained shear strength of cohesive soil is normally evaluated from the unconfined compression test. The cohesive strength (c) can be derived from-

$c = q_u / 2$ (kN/m²) ---- *Braja M. Das, Principles of Foundation Engineering Seventh Edition*

Where-

c = cohesive strength (kN/m²)

q_u = unconfined compressive strength (kN/m²)

However, undrained cohesive strength can also be determined from direct shear test (for reference) and unconsolidated undrained triaxial compression test of undisturbed soil samples.

For sandy soil and hard clayey soil, as the undisturbed sample cannot be easily collected, the cohesive strength can be reliably derived from SPT N-value as following equation –

$c = 50N/8$ (kN/m²) ---------- *(Terzaghi and Peck)*

The relation of SPT N-value and unconfined compressive strength (q_u) is illustrated in Figure-5.1.

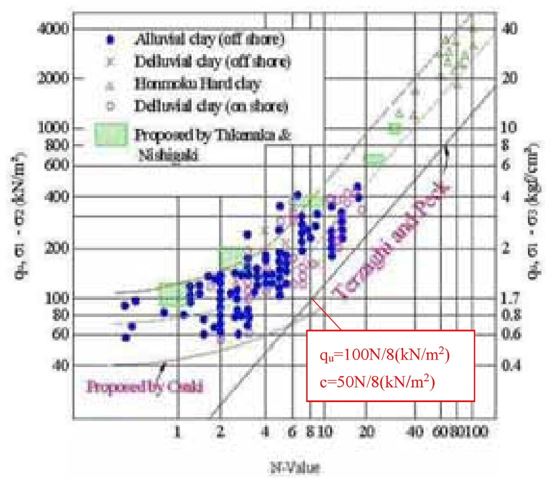


Figure - 5.1 Empirical Relation of N-value and Unconfined Compressive Strength for Clay

(5) Internal friction angle (ϕ)

The internal friction angle of the granular soil can be directly evaluated from the SPT N-value. The internal friction angle of granular soils is evaluated from their average SPT N-value, in accordance with Figure-5.2. The internal friction angle of such deposits can be also evaluated from equation and the recommended design parameters by NEXCO (See Table-5.1). In case of granular soil, the internal friction angle of soil is estimated from following equation- (Refer to Figure-5.2)

$$\emptyset = \sqrt{20N} + 15$$ --------- ② *in Figure: From Osaki, 1979)*

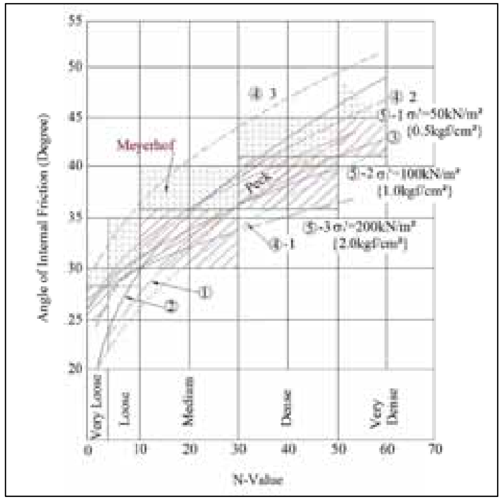


Figure - 5.2 Empirical Relations between N-value and Internal Friction Angle for Sand

(6) Deformation modulus of soil (E)

The deformation modulus of cohesive soil is usually evaluated from the unconfined compression test. For sandy soil and hard clayey soil, as the undisturbed sample cannot be easily taken, the deformation modulus of soil can be evaluated by following equation -

E = 700N (kN/m^2) --------- *Japanese Code*

Where-

E = Deformation modulus of soil (kN/m^2)
N = Number of SPT N-value (measured)

Recommended geotechnical design parameters

Figure-5.3 show the field test results for Letpanchaung Side

Figure-5.4 show the field test results for Pamumchaung Side

Table-5.2 shows the recommended geotechnical design parameters for Letpanchaung Side.

Table-5.3 shows the recommended geotechnical design parameters for Pamumchaung Side.

able - 5.2 Recommended geotechnical design parameters for Letpanchaung Side

No.	Soil Name	N Value	Unit Weight			Internal Friction Angle	Unconfined Compressive Strength	Cohesive Strength	Deformation Modulus
			γ_t (kN/m^3)	γ_{sat} (kN/m^3)	γ' (kN/m^3)	φ (°)	qu (kN/m^2)	c (kN/m^2)	E_{50} (kN/m^2)
1	CLAY-I	2[1)]	14.0[2)]	14.0	4.0	-	25.0[3)]	12.0[3)]	1400[3)]
2	CLAY-II	5[1)]	16.0[2)]	16.0	6.0	-	62.0[3)]	31.0[3)]	3500[3)]
3	Sandy CLAY-I	21[1)]	18.0[2)]	18.0	8.0	-	262.0[3)]	131.0[3)]	14700[3)]
4	Sandy CLAY-II	35[1)]	18.0[2)]	18.0	8.0	-	437.0[3)]	219.0[3)]	24500[3)]
5	Clayey SAND-I	30[1)]	19.0[2)]	19.0	10.0	39[3)]	-	-	21000[3)]
6	Clayey SAND-II	50[1)]	19.0[2)]	19.0	10.0	45[3)]	-	-	35000[3)]
7	Silty SAND-I	35[1)]	19.0[2)]	19.0	10.0	45[3)]	-	-	24500[3)]
8	Silty SAND-II	50[1)]	19.0[2)]	19.0	10.0	45[3)]	-	-	35000[3)]

Table - 5.3 Recommended geotechnical design parameters for Letpanchaung Side

No.	Soil Name	N Value	Unit Weight			Internal Friction Angle	Unconfined Compressive Strength	Cohesive Strength	Deformation Modulus
			γ_t (kN/m^3)	γ_{sat} (kN/m^3)	γ' (kN/m^3)	φ (°)	qu (kN/m^2)	c (kN/m^2)	E_{50} (kN/m^2)
1	Clayey SAND-I	50[1)]	19.0[2)]	19.0	10.0	45[3)]	-	-	35000[3)]
2	Silty SAND-I	48[1)]	19.0[2)]	19.0	10.0	45[3)]	-	-	33600[3)]
3	Silty SAND-II	50[1)]	19.0[2)]	18.0	8.0	45[3)]	-	-	35000[3)]
4	Sandy GRAVEL	50[1)]	20.0[2)]	18.0	8.0	45[3)]	-	-	35000[3)]

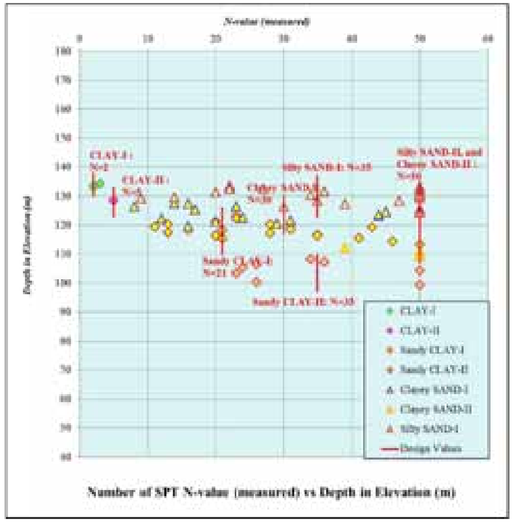


Figure - 5.3 Distribution of SPT N-values

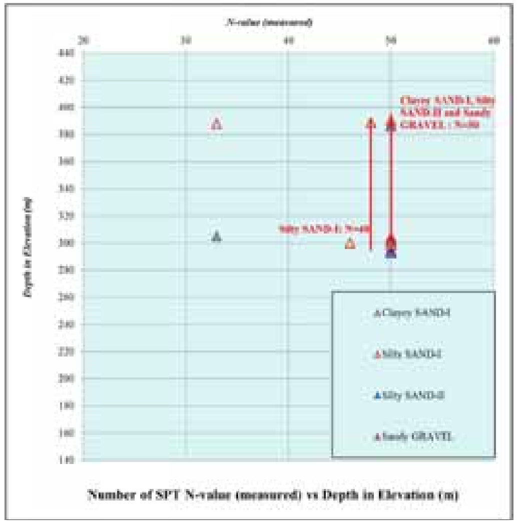


Figure - 5.4 Distribution of SPT N-values

5.2 Bearing Capacity of Shallow Foundation

The bearing capacity of shallow foundation is generally calculated based on the proposed building plan and structural loads that are indicated by client. In this project, as the client have no detailed assigned structural plan and load, and three numbers of bore holes have been carried out for project area. The thickness and the properties of soil layers, and water table condition for proposed area are referred from the investigation results of both field tests and laboratory tests.

In this analysis, the inclination of structural load is regarded as vertical and the inclination angle (θ°) is taken as 0 and the inclination factors (i.e. i_c, i_γ, i_q) become 1. The thickness and engineering properties of the soil stratum is referred from the boring results.

In this analysis, the shallow footing of square shape is proposed in depth of 1.0m from ground level. Therefore, the footing would be founded on Sandy GRAVEL layer for BH-05 (Pamumchaung Side) and Silty SAND-I layer for BH-07 (Pamumchaung Side). In addition, the ground water levels are recorded during field investigation, however, it may change seasonally. Therefore, the water table is regarded as ground level for the project areas. The bearing capacity was calculated using modified Terzaghi's bearing capacity formula.

$$qa = \frac{1}{F_s}(i_c \propto CN_c + i_\gamma\,\beta\,\gamma_1 B\,\eta\,N_\gamma + i_q\,\gamma_2\,D_f\,N_q)$$

Here,

q_a : Allowable Bearing Capacity
F_s : Safety Factor (3)
c : Cohesion of the Ground below the Foundation
γ_1 : Unit Weight of the Ground below the Foundation
γ_2 : Unit Weight of the Ground above the Foundation
D_f : Penetration Depth (Depth from Surface to Foundation Bottom)
α : Shape Factor (Table-5.5)
β : Shape Factor
N_c : Bearing Capacity Factor (Table-5.6)
N_γ : Bearing Capacity Factor (Table-5.6)
N_q : Bearing Capacity Factor (Table-5.6)
i_c : Angle of inclination of Load
i_γ : Angle of inclination of Load
i_q : Angle of inclination of Load
η : Coefficient of correction $(B/B_0)^{-1/3}$, B_0=1m)
B : Long Width of Foundation
L : Short Width of Foundation

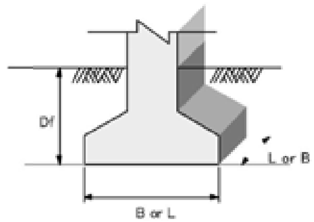


Table - 5.4 Shape Factor

Shape of Foundation	Continuity	Square	Rectangle	Circle
	1.0	1.3	1.0 + 0.3 x B/L	1.3
	0.5	0.4	0.5 - 0.1 x B/L	0.3

Table - 5.5 Bearing Capacity Factor

	N_c	N_q	N_γ
0°	5.14	1.00	0.00
5°	6.49	1.57	0.070
10°	8.35	2.47	0.367
15°	10.98	3.94	1.129
20°	14.83	6.40	2.871
25°	20.72	10.66	6.765
28°	25.80	14.72	11.190
30°	30.14	18.40	15.668
32°	35.49	23.18	22.022
34°	42.16	29.44	31.145
35°	46.12	33.30	37.152
36°	50.59	37.75	44.426
38°	61.35	48.93	64.073
40°	75.31	64.20	93.690
45°	133.88	134.88	262.739

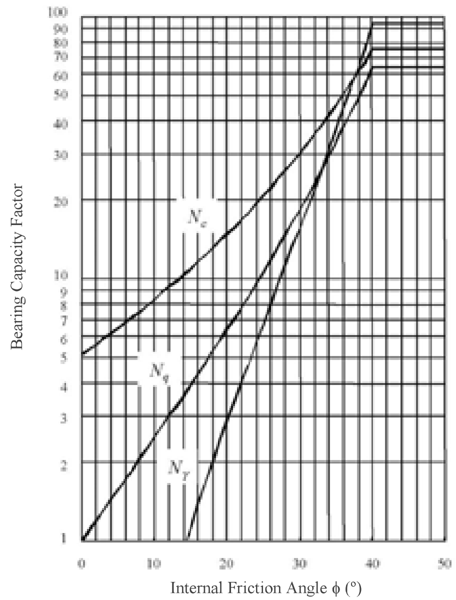


Figure - 5.5 Bearing Capacity Factor

In this analysis, the footing shapes are two types (1.0 x 1.0)m and (2.0 x 2.0)m square shapes. The detailed calculation are as follows.

Shallow Foundation for BH-05 (Letpancahung Side) on Sandy Gravel layer

(1) Calculation Condition for (1.0 x 1.0)m Square Shape

B =	1.00	m		α =	1.300
L =	1.00	m		β =	0.400
D_f =	1.00	m		η =	1.000
γ_1 =	20.00	kN/m^3			
γ_2 =	20.00	kN/m^3		c =	0.00
N value =	30.00				
ϕ =	45.00	°	(Internal Friction Angle)		
θ =	0.00	°	(Angle of Load)		
N_c =	13..88			i_c =	1.00
N_γ =	262.739			i_γ =	1.00
N_q =	134.88			i_q =	1.00

Calculation Results

q_a = 1/3 x (1 x 1.3 x 0.0 x 133.88 + 1 x 0.4 x 20 x 1 x 1 x 262.739 + 1 x 20 x 1.0 x 134.88)

= 1583.84 kN/m^2

Allowable bearing capacity of foundation = q_a x Area of Foundation = 1583.84x 1 = 1583.84 kN

(2) Calculation Condition for (2.0 x 2.0)m Square Shape

B =	2.00	m		α =	1.300
L =	2.00	m		β =	0.400
D_f =	1.00	m		η =	1.000
γ_1 =	20.00	kN/m^3			
γ_2 =	20.00	kN/m^3		c =	0.00
N value =	30.00				
ϕ =	45.00	°	(Internal Friction Angle)		
θ =	0.00	°	(Angle of Load)		
N_c =	133.88			i_c =	1.00
N_γ =	262.739			i_γ =	1.00
N_q =	134.88			i_q =	1.00

Calculation Results

q_a = 1/3 x (1 x 1.3 x 0.0 x 133.88 + 1 x 0.4 x 20 x 2 x 1 x 262.739 + 1 x 20 x 1.0 x 134.88)

= 2277.47 kN/m^2

Allowable bearing capacity of foundation = q_a x Area of Foundation = 2277.47x 2 = 4554.94 kN

Shallow Foundation for BH-07 (Letpancahung Side) on Silty SAND-I layer

(1) Calculation Condition for (1.0 x 1.0)m Square Shape

B =	1.00	m	α =	1.300	
L =	1.00	m	β =	0.400	
D_f =	1.00	m	η =	1.000	
γ_1 =	19.00	kN/m^3			
γ_2 =	19.00	kN/m^3	c =	0.00	
N value =	30.00				
ϕ =	45.00	°	(Internal Friction Angle)		
θ =	0.00	°	(Angle of Load)		
N_c =	133.88		i_c =	1.00	
N_γ =	262.739		i_γ =	1.00	
N_q =	134.88		i_q =	1.00	

Calculation Results

q_a = 1/3 x (1 x 1.3 x 0.0 x 133.88 + 1 x 0.4 x 19 x 1 x 1 x 262.739 + 1 x 19 x 1.0 x 134.88)

= 1504.65 kN/m^2

Allowable bearing capacity of foundation = q_a x Area of Foundation = 1504.65x 1 = 1504.65 kN

(2) Calculation Condition for (2.0 x 2.0)m Square Shape

B =	2.00	m	α =	1.300	
L =	2.00	m	β =	0.400	
D_f =	1.00	m	η =	1.000	
γ_1 =	19.00	kN/m^3			
γ_2 =	19.00	kN/m^3	c =	0.00	
N value =	30.00				
ϕ =	45.00	°	(Internal Friction Angle)		
θ =	0.00	°	(Angle of Load)		
N_c =	133.88		i_c =	1.00	
N_γ =	262.739		i_γ =	1.00	
N_q =	134.88		i_q =	1.00	

Calculation Results

q_a = 1/3 x (1 x 1.3 x 0.0 x 133.88 + 1 x 0.4 x 19 x 2 x 1 x 262.739 + 1 x 19 x 1.0 x 134.88)

= 2163.87 kN/m^2

Allowable bearing capacity of foundation = q_a x Area of Foundation = 2163.87x 2 = 4327.73 kN

5.3 Bearing Capacity of Pile Foundation for Letpanchaung Side

As the proposed construction project is heavy load structure. Therefore, pile foundation should be applied for this construction project. The bearing capacities of bore pile (end bearing capacity and skin friction) are estimated from boring results especially from SPT-N value.

For the evaluation of bearing capacity of pile foundations, the formula for calculation of bearing capacity of bored pile, derived from "Recommendation for Design of Building Foundations (2001) by Architectural Institute of Japan" would be applied for this analysis.

In calculation of end bearing capacity in bore pile, N < 4 will not be consider because it represents soft condition of soil and it is not enough to calculate skin friction of piles.

15. For Bore Pile

$$R_u = R_p + R_f \ (kN)$$

$$R_p = q_p A_p,\ R_f = R_{fs} + R_{fc} \ (kN)$$

Where,

R_u = Ultimate bearing capacity of pile (kN)
R_p = End bearing capacity of pile (kN)
q_p = End bearing capacity per square meter (kN/m^2)
A_p = Area of pile (m^2)
R_f = Skin friction of pile (kN)
R_{fs} = Skin friction of sandy soil layer (kN) = $\tau_s L_s \psi$
R_{fc} = Skin friction of cohesive soil layer (kN) = $\tau_c L_c \psi$
L_s = Length of sandy soil layer portion surrounding pile (m)
L_c = Length of cohesive soil layer portion surrounding pile (m)
τ_s = Skin friction of sandy soil layer portion surrounding pile per square meter (kN/m^2)
τ_c = Skin friction of cohesive soil layer portion surrounding pile per square meter (kN/m^2)
ψ = Length of circumference of pile (m)

End bearing (q_p)

q_p = 100 N′ (kN/m^2) for sandy soil
N′ = Average Converted N-value between upper 1D and lower 1D from pile end
D = Pile diameter (m)
Converted N = 100 as a maximum value is acceptable for the above formula
q_p = 7,500 kN/m^2 as a maximum value is acceptable for the above formula

q_p = 6 Cu (kN/m^2) for cohesive soil
Cu = cohesion of cohesive soil at the pile end (kN/m^2)
q_p = 7,500 kN/m^2 as a maximum value is acceptable for the above formula

Skin friction (τ)

τ_s = 3.3 N (kN/m^2) for sandy soil

N = 50 as a maximum value is acceptable for the above formula

τ_c = Cu (kN/m^2) for cohesive soil

Cu = cohesion of cohesive soil at the pile end (kN/m^2)

Cu = 100 kN/m^2 as a maximum value is acceptable for the above formula

In this calculation, the diameter of pile is estimated 0.8m for bore pile. The average SPT N-value for each meter is calculated for each borehole during calculation of bearing capacity of bored pile. The detailed calculation sheet is attached in Appendix-F. Table-5.6 shown the summary of allowable bearing capacity, skin friction and end bearing capacity of each borehole for bore pile. Figure-5.6 shown the distribution of allowable bearing capacity of bore pile with depth in elevation. Moreover, Figure-5.7 and 5.8 show the allowable bearing capacity, skin friction and end bearing of bore pile for each borehole.

Table - 5.6 The allowable bearing capacity, end bearing capacity and skin friction for Bore Pile

BH-No.	Bottom depth of Borehole GL-(m)	End Bearing Capacity (kN)/Pile	Skin Friction (kN)/Pile	Allowable Bearing Capacity (kN)/Pile
BH-01	35.0m	657	8,911	3,189
BH-02	25.0m	3,750	7,020	3,590
BH-02	22.0m	3,750	6,671	3,473

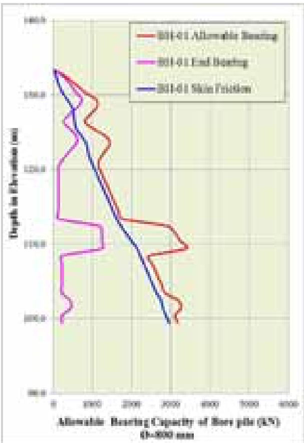
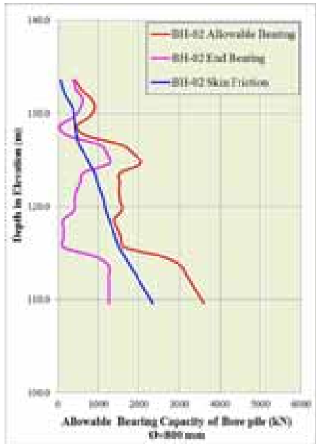


Figure - 5.6 Distribution of allowable bearing capacity for bore pile vs depth in elevation (m)

Report On Topographic Survey and Soil Investigation at Chin State
Falam and Tedim Township, Chin State



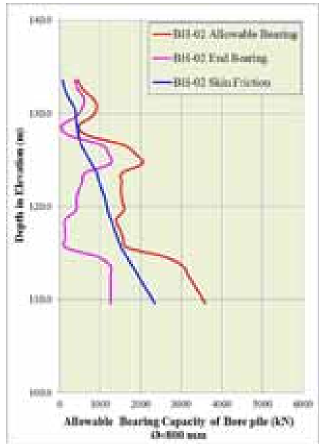


Figure - 5.7 Distribution of allowable bearing capacity, end bearing and skin friction for bore pile with depth in elevation of BH-01 & BH-02

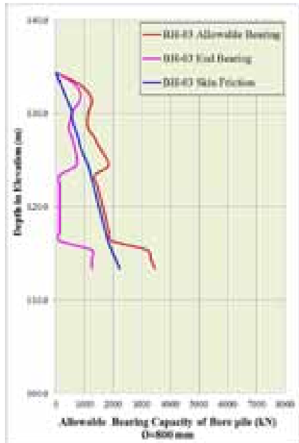


Figure - 5.8 Distribution of allowable bearing capacity, end bearing and skin friction for bore pile with depth in elevation of BH-03

5.4 Earthquake Consideration

By the global scope of geology, Myanmar lies in one of the great earthquake provinces called the Alpine Earthquake Belt. Therefore, minor to catastrophic earthquakes has occurred many times in the territory of Myanmar since long ago. The central and eastern part of Myanmar lies on the Burma Plate which has a convergent boundary with Indian Plate in the western most part of Myanmar. The Burma Plate has been relatively moving 2 to 3 cm per year to the north. Due to this unstable activity of ground earthquake occurrences can expect at any time in Myanmar.

5.4.1 Earthquake Intensity of Myanmar

Earthquake intensity in the area can be seen in Figure-5.9. The map is an earthquake probable intensity zoning map. The approach is mainly empirical and historical in the sense that it makes use of past seismic event and history to make educated guesses about region wide intensities in the future. It is hoped that a probabilistic seismic risk (or earthquake hazard map) on horizontal ground acceleration should be taken into account in the design.

As shown in the map, five seismic zones are demarcated and named (from low to high) Zone I (Low Zone), Zone II (Moderate Zone), Zone III (Strong Zone), Zone IV (Severe Zone), and Zone V (Destructive Zone), mainly following the nomenclature of the European Macro seismic Scale 1992. For each zone, a probable range of ground acceleration in g values and equivalent Modified Mercalli (MM) Scale classes are given. The highest intensity zone designated for Myanmar is the Destructive Zone (with probable intensity range of 0.4-0.5 g) which is equivalent to MM class IX. There are four areas in that zone; namely, Bago-Phyu, Mandalay-Sagaing-Tagaung, Putao-Tanaing, and Kale Myo-Homalin areas. The latter two, however, would not have major earthquake hazards as they are only sparsely populated. Important cities and towns that lie in Zone IV (Severe Zone, with probable intensity range of 0.3-0.4 g) are Taungoo, Taungdwingyi, Bagan-Nyaung-U, Kyaukse, PyinOoLwin, Shwebo, Wuntho, Hkamti, Haka, Myintkyina, Taunggyi, and Kung long. Yangon straddles the boundary between Zone II and Zone III, with old and new satellite towns in the eastern part in Zone III, and the original city in Zone II. Regarding the Modified Mercalli (MM) Scale classes, the level of probable damage and destruction may be summarized as in Table-5.7.

Table - 5.7 The Level of Probable Damage and Destruction

Zone	MM Class	Probable Damage	Examples of Damage
V	IX	Major damage	Considerable damage in specially designed structures Major damage in good RC buildings
IV	VIII-IX	Considerable damage	Considerable damage in good RC buildings Major damage in ordinary brick buildings
III	VIII	Moderate damage	Moderate damage in good RC buildings Considerable damage in ordinary brick buildings
II	VII	Minor damage	Minor damage in good RC buildings Moderate damage in ordinary brick buildings
I	VI	Slight damage	Minor damage in ordinary brick buildings

According to the seismic zone map of Myanmar (after Dr. Maung Thein et.al, 2005 Dec), the project area is shown in Figure-5.9

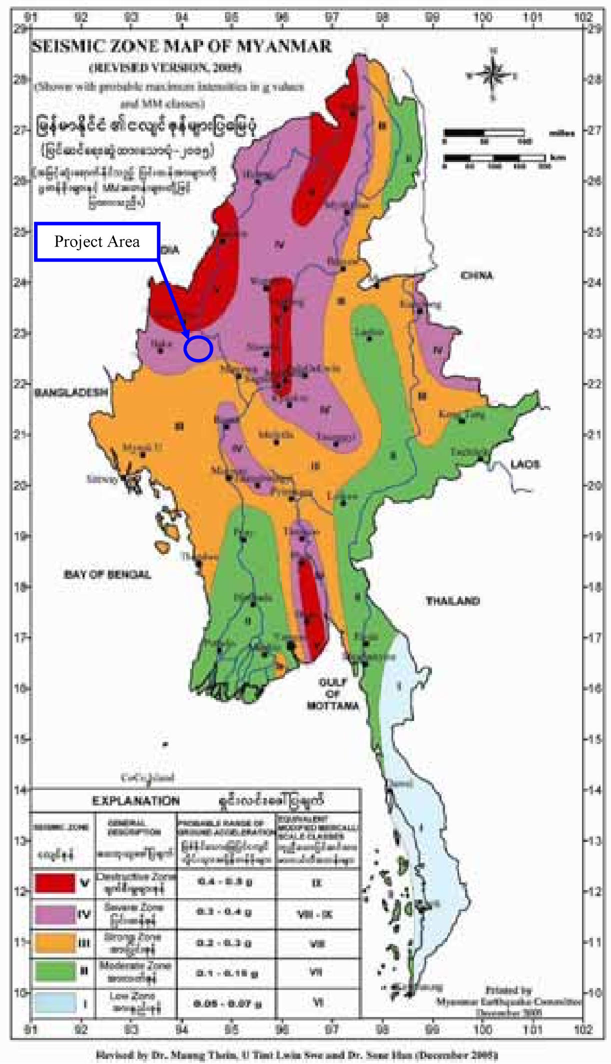


Figure - 5.9 Seismic Zone Map of Myanmar (after Dr. Maung Thein et.al, 2005 Dec)

Liquefaction is one of the catastrophic of earthquake related hazards. According to the investigation results, engineering properties of some soil layers have been identified as potential of liquefaction. According to the theoretical research, the quicksand is high potential to liquefaction. The term quicksand (after Terzaghi, 1925) is referred to three conditions. First the sand or silt concerned must be saturated and loosely packed. Second, on disturbance of constituents grains become more closely packed, which leads to an increase in pore water pressure, reducing the forces acting between the grains. This brings about a reduction in strength. The third condition requires that pore water cannot escape readily. This is fulfilled if the sand or silt has a low permeability and/or the seepage path is long. As the above reasons, poorly graded sand of fine to medium grained and silty sand of saturated condition have high potential to liquefaction. Liquefaction of potential quicksand may also be brought about by sudden shocks caused by the action of heavy machinery and blasting.

According to the investigation results for a lot of earthquake experience in the world, it is said that the liquefaction can occur easily under the following condition.

1) Lower fine content of saturated soil (Fine content is meant the size less than 0.07 mm)
2) Lower SPT blow count (N) of saturated soil (SPT N-value < 20 blows per 30 cm)
3) Shallow groundwater table
4) Bigger maximum peak acceleration

5.4.1.1 Liquefaction Analysis Procedure

In this analysis, magnitude of earthquake and peak acceleration at ground surface is assumed as 0.4g, and MM Class is 8.0 in this area. And, water table is actual water level from investigation results.

Liquefaction analysis is performed by following two methods:

"Highway Bridge Design Guideline, Anti-earthquake design Chapter" Japan Road Association, 2012.3

Method by Highway Bridge Design Guideline

① Object Soil Layers for Liquefaction Analysis

(a) The soil layer of which groundwater level is less than 10m from ground surface, and exists in the depth within 20m from ground surface

(b) The soil layer of which fine content (FC) is less than 35% or even if fine content (FC) exceeds 35%, plasticity Index (Ip) is less than 15.

(c) The soil layer which is D_{50} [50% particle diameter] is below 10mm, and D_{10} [10% particle diameter] is a soil layer below 1 mm".

② Calculation of Safety factor against Liquefaction

$$F_L = R/L$$

$$R = c_w R_L$$

$$L = r_d k \; \sigma_v / \sigma_v'$$

$$r_d = 1.0 - 0.015x$$

$$k_{hgL} = c_z k_{hgL0}$$

Since a horizontal seismic coefficient is about 0.2, level 1 earthquake motion is assumed.

$$c_w = 1.0$$

Where,

F_L = Liquefaction resistance ratio
R = Liquefaction strength ratio
L = Earthquake shear stress ratio
c_w = Correction factor by earthquake vibration properties
R_L = The repetition triaxiality strength ratio
r_d = Reduction coefficient of the depth of the earthquake shear stress ratio
k_{hgL} = Design horizontal seismic intensity of the ground surface to use for a judgment of the liquefaction (assumed to be 0.2 for the project area)
c_z = Seismic zone factor. Here, it was set with 1.0.
k_{hgL0} = Standard value of the design horizontal seismic intensity of the ground surface to use for a judgment of the liquefaction
σ_v = The total pressure exerted by earth
σ_v' = The effective overburden pressure
x = Depth from an earth surface

The repetition triaxiality strength ratio "R_L" is computed by following formula:

$R_L = 0.0882\sqrt{N_a}/1.7$ (Na＜14)

$R_L = 0.0882\sqrt{N_a}/1.7 + 1.6 \times 10^{-6} \cdot (N_a - 14)^{4.5}$ (Na≧14)

<In case of a sandy soil>

$N_a = c_1 N_1 + c_2$

$N_1 = 170\, N / (\sigma'_{vb} + 70)$

Where,

$c_1 = 1$ (0%≦FC＜10%)

$c_1 = (FC + 40)/50$ (10%≦FC＜60%)

$c_1 = FC/20 - 1$ (60%≦FC)

$c_2 = 0$ (0%≦FC＜10%)

$c_2 = (FC - 10)/18$ (10%≦FC)

<In case of a gravely soil>

$N_a = \left\{1 - 0.36 \log_{10}\left(D_{50}/2\right)\right\} N_1$

Where,

R_L ＝ The dynamic shear strength ratio
N ＝ N-value
N_1 ＝ N-value converted into the effective overburden pressure 100kN/m^2
σ_{vb}' ＝ The effective overburden pressure in the depth of SPT (kN/m^2)
c1,c2 ＝ The correction factor of N-value by the content for an infinitesimal grain
FC (%) ＝ Fines Content (Percent less than 0.075mm)

D_{50}(mm) ＝ 50% particle size

5.4.1.2 Potential of Liquefaction (P_L)

P_L was originally developed in Japan to estimate the potential of liquefaction to cause foundation damage at a site (Iwasaki, 1978). P_L assumes that the severity of liquefaction is proportional to the:

(1) Thickness of the liquefied layer;
(2) Proximity of the liquefied layer to the surface; and
(3) Amount by which the factor of liquefaction (F_L)

The potential of liquefaction can be calculated by following formula;

$$PL = \int_0^{20} (1 - FL)(10 - 0.5z)\, dz$$

Where,

P_L = potential of liquefaction
F_L = factor of liquefaction
z = Depth in meters

Potential of liquefaction condition is shown in Table-5.8.

Table - 5.8 Potential of Liquefaction condition

15 < P_L	High Possibility of Liquefaction
5 < P_L ≤ 15	Possibility of Liquefaction
0 < P_L ≤ 5	Low Possibility of Liquefaction

5.4.1.3 Except Expected Ground Acceleration at site

According to the seismic zone map of Myanmar, the probable ground peak acceleration when earthquake occur will be 0.4g. In addition, the Modified Mercalli (MM) class of Kalay can be regarded as 8.0.

5.4.2 Liquefaction Analysis Results for BH-01, BH-02 and BH-03(Letpanchaung Side)

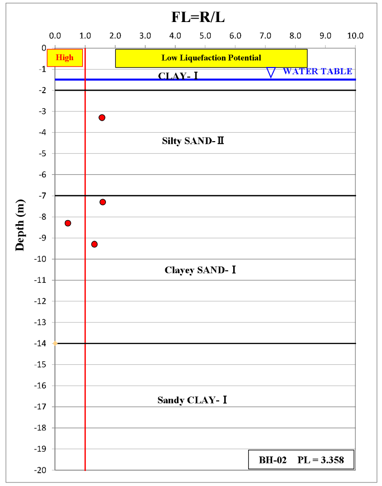
Generally, if the earthquake occur in this area, the liquefaction potential will be high in Silty SAND layers. According to the liquefaction analysis results, the liquefaction potential is high in sandy soil layers. Because of the water table is shallow (around GL-1.0m from the ground level), the relative density of sandy soil layer very loose to medium dense in some depths and bigger maximum peak ground acceleration. Summary of liquefaction analysis results are shown in Table-5.9, and the distribution of liquefaction potential are shown in Figure-5.14 and 5.15. Potential of liquefaction is shown in Table-5.10. The detailed calculation is attached in Appendix-G.

Table - 5.9 Summary of Liquefaction Analysis Results

Depth (m)	BH-01		BH-02		BH-03	
	Soil Layer Name	Possibility of liquefaction	Soil Layer Name	Possibility of liquefaction	Soil Layer Name	Possibility of liquefaction
1.300	CLAY-I	Low	Silty SAND-I	Low	CLAY-I	Low
2.300	Silty SAND-I	Low	Silty SAND-I	Low	Silty SAND-I	Low
3.300	Silty SAND-I	Low	Silty SAND-I	Low	Silty SAND-I	Low
4.300	Silty SAND-I	Low	Silty SAND-I	Low	Silty SAND-I	Low
5.300	Silty SAND-I	Low	Silty SAND-I	High	Silty SAND-I	Low
6.300	Silty SAND-I	Low	CLAY-II	Low	Silty SAND-I	High
7.300	Clayey SAND-I	Low	Clayey SAND-I	High	Silty SAND-I	Low
8.300	Clayey SAND-I	High	Clayey SAND-I	High	Silty SAND-I	Low
9.300	Clayey SAND-I	Low	Clayey SAND-I	Low	Silty SAND-I	High
10.300	Clayey SAND-I	Low	Clayey SAND-I	Low	Silty SAND-I	Low
11.300	Clayey SAND-I	Low	Clayey SAND-I	Low	Silty SAND-I	Low
12.300	Clayey SAND-I	Low	Clayey SAND-I	High	Sandy CLAY-I	Low
13.300	Clayey SAND-I	Low	Clayey SAND-I	Low	Sandy CLAY-I	Low
14.300	Sandy CLAY-I	Low	Clayey SAND-I	High	Sandy CLAY-I	Low
15.300	Sandy CLAY-I	Low	Clayey SAND-I	High	Sandy CLAY-I	Low
16.300	Sandy CLAY-I	Low	Sandy CLAY-I	Low	Sandy CLAY-I	Low
17.300	Sandy CLAY-I	Low	Sandy CLAY-I	Low	Sandy CLAY-I	Low
18.300	Sandy CLAY-I	Low	Sandy CLAY-I	Low	Sandy CLAY-I	Low
19.300	Sandy CLAY-I	Low	Sandy CLAY-I	Low	Sandy CLAY-I	Low

Table - 5.10 P_L value of each boreholes

Borehole No	P_L value
BH-01	3.36
BH-02	14.22
BH-03	5.20



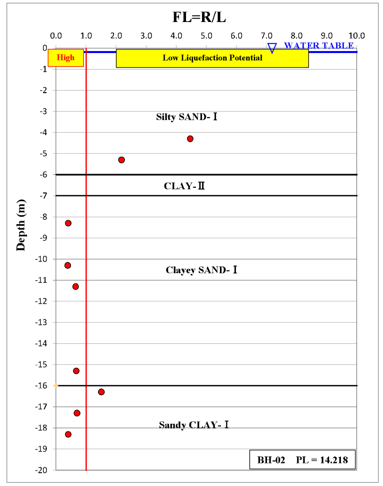


Figure - 5.10 Distribution of liquefaction potential of BH-01 & BH-02

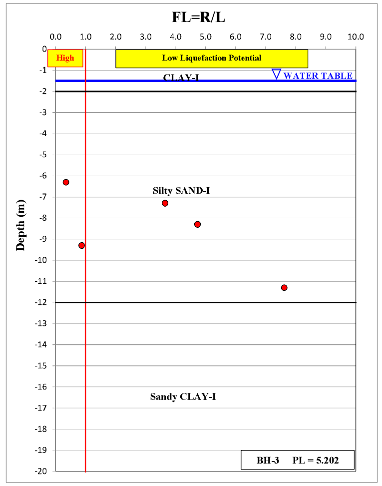


Figure - 5.11 Distribution of liquefaction potential of BH-03

6 CONCLUSION AND RECOMMENDATION

6.1 General Information

JICA PROJECT TEAM is planning to construct the bridges and other related structures at Falam and Tedim Township, Chin State. Therefore, Fukken Co., Ltd. was assigned to conduct soil investigation works to obtain soil properties of selected locations in the project area. The soil investigation was carried out to obtain the information about the stratigraphic composition at site, the distribution of the reliable bearing layer and geotechnical design parameters. Total six boreholes were carried out on the proposed project area. According to the soil investigation works, three portions are included in this report. There are as follow.

(1) Field Test includes SPT test, Disturbed Soil Sampling, Water Sampling and Water Level Measuring

(2) Laboratory Test Results (Physical Properties Test)

(3) Report with geotechnical assessments

6.2 Ground Conditions

According to the two location soil investigation results, total nine different soil layers are observed at BH-01, BH-02 and BH-03(Letpanchaung Side) and total six different soil layer for BH-05, BH-06 and BH-07(Pamumchaung Side) in this investigation project. These different layers are described as follows.

Soil layer for Letpanchaung side

BH-01, BH-02 and BH-03

16. CLAY-I
17. CLAY-II
18. Sandy CLAY-I
19. Sandy CLAY-II
20. Clayey SAND-I
21. Clayey SAND-I
22. Silty SAND-I
23. Silty SAND
24. SANDSTONE(Rock)

Soil layer for Pamumchaung side

BH-05, Bh-06 and BH-07

8. Clayey SAND-I
9. Silty SAND-I
10. Silty SAND-II
11. Sandy GRAVEL
12. LIMESTONE(Rock)
13. SHALE(Weathered Soil)
14. SANDSTONE(Rock)

According to the Standard Penetration Test "SPT" results, the distribution of SPT N-value for each soil layer for Letpanchaung Side and Pamumchaung Side are illustrated in (Table-6.1 and 6.2) & (Figure-6.1and Figure-6.2). Moreover, soil profile through the project area of Letpanchaung Side and Panmumchaung Side are shown in Figure-6.3 to Figure-6.6.

Table - 6.1 Distribution of SPT N-value for each soil layer for Letpanchaung Side

Sr No.	Soil layer	N-value (Measured)						Minimum	Maximum	Average
		10	20	30	40	50	60			
1	CLAY-I							2	3	2
2	CLAY-II							5	5	5
3	Sandy CLAY-I							11	50	27
4	Sandy CLAY-II							23	50	34
5	Clayey SAND-I							8	50	37
6	Clayey SAND-II							38	50	47
7	Silty SAND-I							9	50	37
8	Silty SAND-II							42	50	50

Table - 6.2 Distribution of SPT N-value for each soil layer for Pumumchaung Side

Sr No.	Soil layer	N-value (Measured)						Minimum	Maximum	Average
		10	20	30	40	50	60			
1	Clayey SAND-I							50	50	50
2	Silty SAND-I							33	50	50
3	Silty SAND-II							50	50	50
4	Sandy GRAVEL							33	50	50

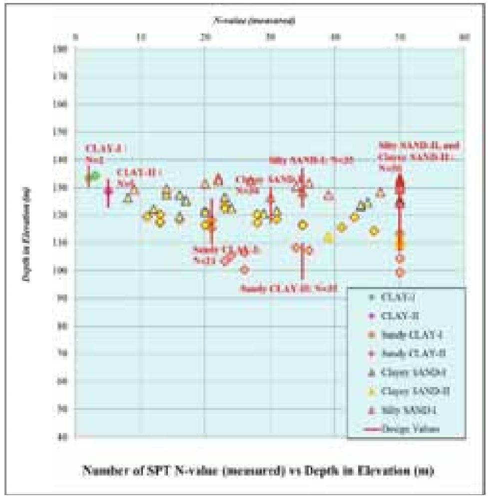


Figure - 6.1 Distribution of SPT N-values of the project area for Letpanchaung Side

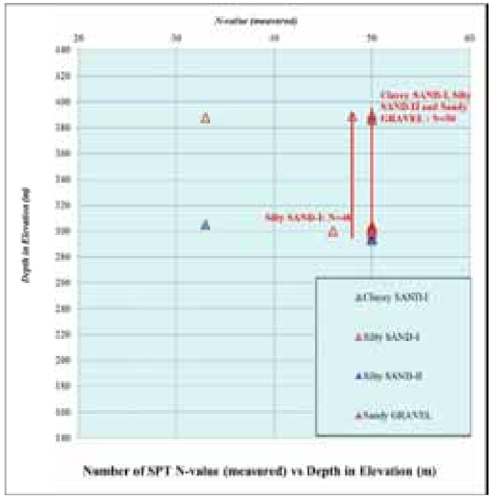


Figure - 6.2 Distribution of SPT N-values of the the project area for Letpanchaung Side

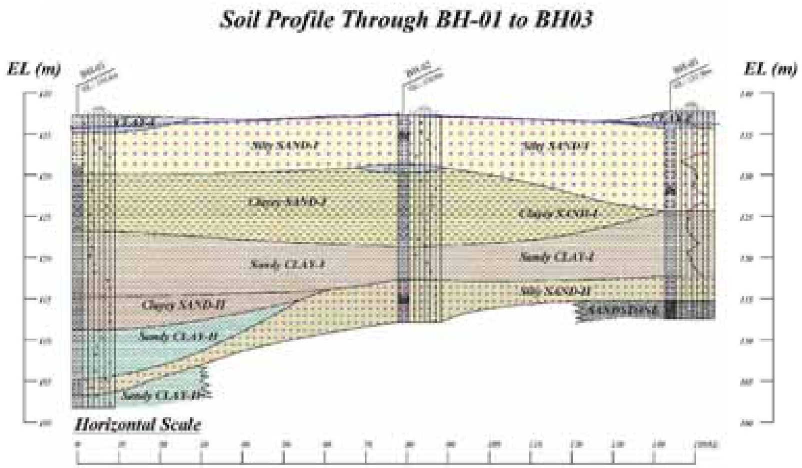


Figure - 6.3 Soil profile through the project area for Letpanchaung Side

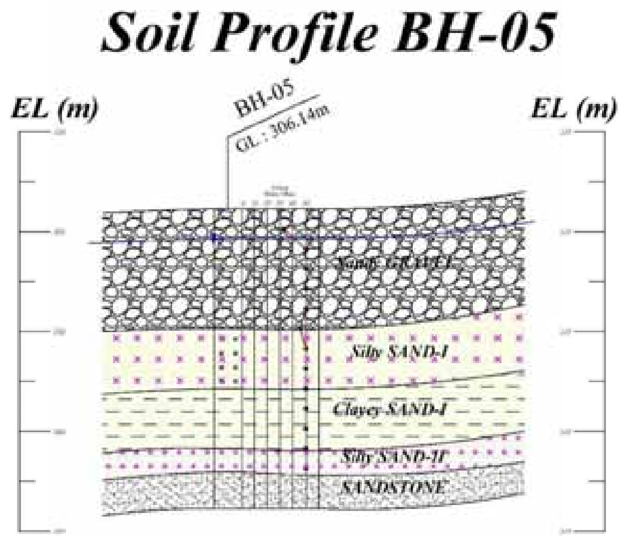


Figure - 6.4 Soil profile for BH-05 (Pamumchaung Side)

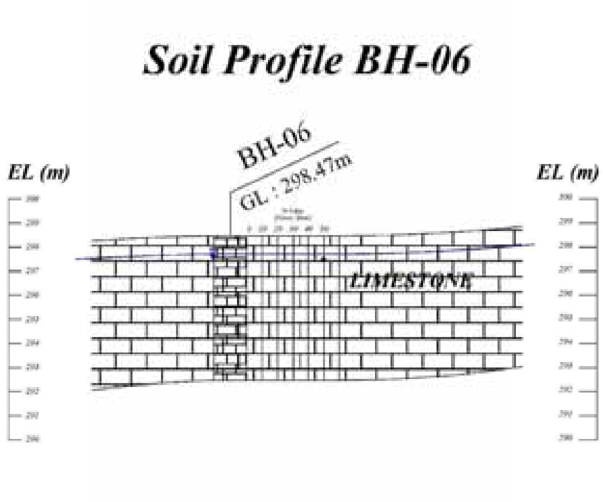


Figure - 6.5 Soil profile for BH-06 (Pamumchaung Side)

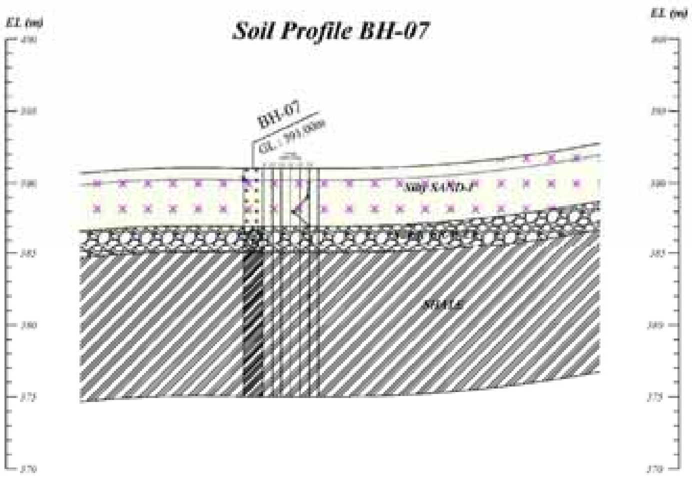


Figure - 6.6 Soil profile for BH-07 (Pamumchaung Side)

6.3 Type of Foundation

As the proposed construction project is designed with light load structure, the shallow foundation should be applied for proposed construction project. According to the investigation results, Sandy GRAVEL layer can be estimated as bearing layer for light load structure with suitable diameter of footing for BH-05(Pamumchaung Side) and Silty SAND-I layer for BH-07(Pamumchaung Side).

If the proposed construction is heavy load structure, pile foundation is recommended for proposed construction project at BH-01, BH-02 and BH-03(Letpanchaung Side). The diameter of pile is estimated 0.8m for bore pile. The average SPT N-value for each meter is calculated for each borehole during calculation of bearing capacity of bored pile Therefore, the calculation results may have a little different value due to different calculation methods. However, these estimated values can use general information for proposed construction project. According to the investigation results, safe reliable bearing layer is Silty SAND-II layer. The distribution of allowable bearing capacity for bore pile and depth in elevation (m) for each borehole are presented in Figure-6.7.

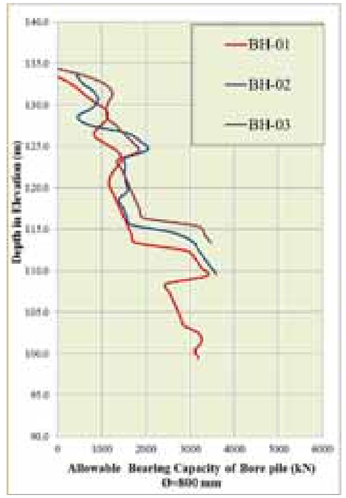


Figure - 6.7 Distribution of allowable bearing capacity for driven pile vs depth in elevation (m)

6.4 Seismic Consideration

The detailed calculation are presented in Appendix-G. According to the investigation results, the clayey soil layers are well observed in this project area. Generally, if the earthquake occur in this area, the liquefaction potential will be high in Silty SAND and Clayey SAND layers. According to the liquefaction analysis results, the liquefaction potential is spotted high in Silty SAND layer at BH-01 and BH-03. However, liquefaction thickness of BH-02 is more than 6m. Because of the water table is shallow (around the groundsurface), the relative density of sandy soil layer very loose to medium dense in some depths and bigger maximum peak ground acceleration in this project area. The P_L of each borehole for Letpanchaung side is show in Table-6.3.

Table - 6.3 P_L value of each boreholes

Borehole No	P_L value
BH-01	3.36
BH-02	14.22
BH-03	5.20

6.5 Road Material

When roads in the project area will be improved, the road material is planed to be prepared along existing roads in this design.

According to the results of Design CBR Test, CBR values of Point 3 of Road 2 and Point 3 of Road 7 are less than 1%. It is considered that these materials are not available for the road material. Therefore, it is necessary to check the road materials before commencement of construction work.

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