Case Study of Soil Stabilization by Pre-Loading Method Application

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Abstract
Soil stabilization is an old technique that has been used for decades to strengthen and preventing the soil from collapse or undergo of an unacceptable settlement, especially ground that does not have loading capacity, therefore, ground treatment is highly efficient solution. This study describes the deformation behaviour of residential embankment on soft soil with application preloading as the ground improvement method. The embankment was modelled using oedometric modulus analysis of Geo 5 Settlement Software. The soil parameters obtained from the site investigation report were used to simulate the soil behaviour such settlement and degree of consolidation in the software and then, being compared when with and without application of preloading using the software and with Conventional Method for comparison. The result shows that, the with earth fill preloading of 4kPa on the soft ground of selected site is being applied will fasten the consolidation and settlement process to be compared when without preloading. The consolidation for all analysis to be reach 90% consolidation at different time such with preloading application to consolidate at 150 days, 230 days for conventional method and 10,000 days when without preloading application. In conclusion, to ensure the settlement at site to be about predicted settlement, the installation of prefabricated vertical drain is advisable in order to dissipate water faster without produce high settlement value especially during heavy season.

Keywords: Pre-Loading, Soft Soil, Soil Stabilization, Geo-5 Software, Soil Settlement

1. Introduction and Problem Statement

In this recent year's rapid development of infrastructures together with growth of population worldwide had been limited the availability of good soil, hence, the poor soil had been made good by ground improvement techniques (Brajesh, 2016). Moreover, in order to meet the time requirement of a certain project, it is better to replace or bypass or fill the ground by implementing the suitable ground improvement techniques (Brajesh, 2016). There is no need for application of expensive surface treatments to improve durability and water tightness (Houben and Guillaud, 1996).

Shear strength, compressibility, permeability and shrink or swell are the properties or behaviors of soil where, by developing a solution to prevent harmful effect from occurring such as failures is co-related to a soil behavior (Peter, 2015). As the past researchers(Michael and Klaus, 2004) had indicated that all ground improvement techniques are pursuing to improve those soil characteristics such as an increase in density and shear strength to solving problems of stability, to reducing and controlling the ground water flow or improving the soil homogeneity will be unravelling the permeability problem and reducing of soil compressibility by increasing the rate of consolidation. The determination of soil stabilization techniques is depending on the original ground conditions, soil properties and desired outcomes. Furthermore, it will help to resolve the poor site conditions, inadequate soil qualities (Peter, 2015). Stabilization can increase the shear strength of soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to pavements and foundations (Midstate Companies, 2016).

For this study, the stabilization by pre-loading method has been discussed, which is define as load placed on the selected area that is having weak compressible or loose of surface strata such as soft fine-grained silts and clays, organic soils, loose silts and sandy soils (Brajesh, 2016).The advantages of this method are the most effective for soft cohesive soil, help to reduce any post construction settlement, furthermore, the method will be reducing in secondary compression, due to the soil compaction process the stress applied to a soil causes a densification to the selected area and lastly, the advantage of this method will be it help to improve the bearing capacity of the ground. Preloading is the most effective and economical methods to improve the bearing capacity and reduce the settlement of soft soil as it widely used in Malaysia. In addition, this method the cheapest among the other methods and fast in producing the required ending result.

2. Literature Review

2.1 Soil Stabilization

Mitchell (1981) said that the suitability of high strength of soil areas hasdecreased due to the increases in population which lead to high demand in construction of residential building, office building and etc., hence the need to utilize the poor soil areasare increasing and therefore, the necessity to strengthen the poor soil has been widely increased in order to ensure the stability against any excavation, tunneling or to improve seismic resistance or any other loading. Soil stabilization is an old technique that has been used for decades to strengthen and preventing the soil from collapse or undergo of an unacceptable settlement, especially ground that does not have loading capacity, therefore, ground treatment is highly efficient solution (Xavier, 2016).Procedure where a special soil, a cementing material or other chemical or non-chemical materials are added to a natural soil or a technique use on a natural soil to improve one or more of its properties is known as soil stabilization or improvement (Onyelowe, 2012).Sherwood (1993) define soil stabilization as the aim of improving soil strength and increasing resistance to softening by water through bonding the soil particles. Hall, Naim and Keikhaei (2012) declared that soil stabilization as the controlled modification of soil texture, structure and/or physico-mechanical properties. Soil stabilization is a permanent chemical and physical modification of soils (Ruston Paving, 2018).

Ground improvement and soil stabilization techniques are depending on the original ground conditions, soil properties and desired outcomes, in addition it will help together to solve the poor site conditions, inadequate soil qualities and define the mitigation of potential problems or any remedial works (Nicholson, 2015).The simplest stabilization methods are compaction and drainage because once the water is being drained out, the soil becomes stronger in their properties (Makusa, 2012) and other process of improving the soil can be achieved by adding binders to weak soils (Rogers, 1996).Furthermore, Burroughs (2001) mentioned that approaches to stabilization can be broadly classified as physical, mechanical or binding.Tiwari and Kumawat (2014) stated that the main purpose of soil stabilization or improvement is to increase bearing capacity of soil and reduce the settlement to a considerable extend. As per cited by Makusa (2012), the stabilization aims to increase the shear strength of a soil and to control the shrink-swell properties of a soil, therefore, improving the load bearing capacity of a sub-base to support the upper loading.

Vidal (1996) demonstrated and produced rational design approach of using dried earth blocks as soil stabilization or known earlier days as soil reinforcement. Vadodara used geotextiles as ground improvement in the year 1982 for railway track between Ankleshwar and Bharuch cities in Gujarat States, India. Ike introduce the usage of hydrated lime in 2006 to improve the strength, stiffness and durability of fine-grained soil and it has been used as a stabilizer for soil especially in base courses of concrete pavements, embankment slopes and under canal linings on canal slopes, where in earlier year of 1920's the Romans use this technique in temporary road surfaces and road sub-bases which subsoil has a high percentage of cohesive clay.In year 1996, Wirtgen introduce the production of foamed bitumen system as the stabilizing agents for a deeper layer.Circa, Japan develop a trench cutting re-mixing deep method (TRD) in year 1993 which this tool is a blend in-situ soil with cementitious binder to create soil-cement wall where indeed of open trench can be avoid and thus, injection port will be placed into it to inject the grout into treatment zone.

Menard (1970) hadinvented dynamic compaction technique in order to improve the mechanical properties of soil by transmitting high energy impact to the soil. Naudts and Welsh (2000) had proposed the compaction grouting alternative which is the geotextile bags will be inserted into the grouting hole and thus,allow water to slowly filtrate through it because during each grouting stage the pressure is systematically increased due to the geotextile bag will act as resistance against the pressure filtration.Mitchell (1981) had develop this soil modification by blast densification mainly for loose, cohesionless soils in order to increase the density either above or below the water table but this method is mainly carrying out at mining area. In year 1948, Barron introduce the preloading using fill which is a process of applying surcharge load on the ground that is acting as placement of external loads to consolidate the soil until settlement occurs. Inyear 1952, Kjellmanhad improvised the preloading method by introducing the vacuum preloading with vertical drains, where this method is applied when surcharge is higher than maximum value.

2.2 Preloading or Surcharge Method

The advantages of this method are to reduce post construction settlement, reduce secondary compression, improve the bearing capacity, most effective, economical method and cheapest among other methods, whereas, the disadvantages are unexpected increase in cost and unexpected time delay (Mishra, 2016). Makusa (2012) adds that this method will increase the shear strength of a soil, controlling the shrink-swell properties of a soil and improving the bearing capacity of sub-base to support the upper loading.Furthermore, Kambaliya (2015) studies proven that the method will increasing the vertical stress of the poor soil which is shown in Figure 2.1 below.

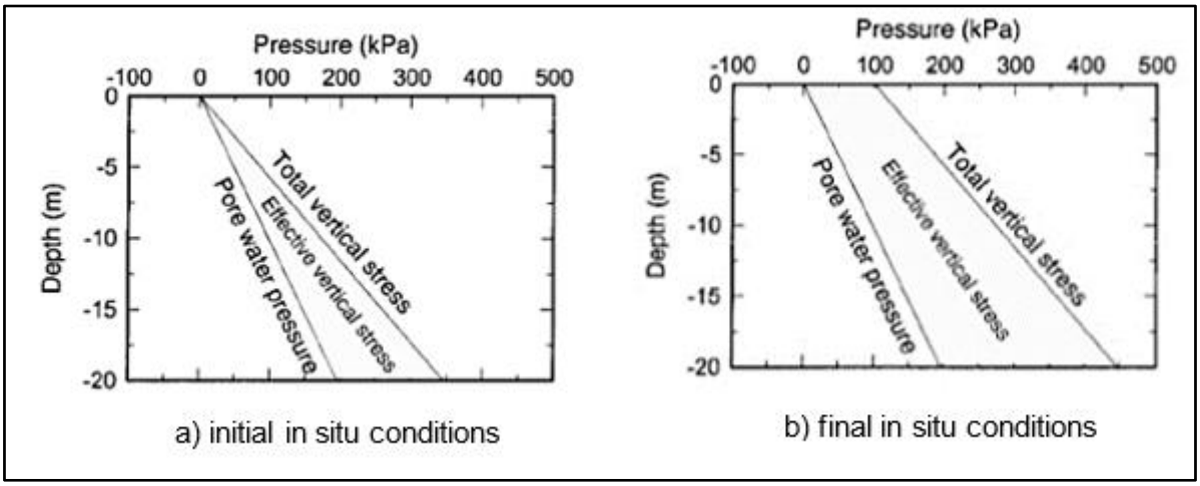


Figure 2.1:Graph of initial and final in-situ conditions of preloading application

According to Mitchell (1981) the main objective of preloading method is design the surcharge loads and duration of their application to reduce the settlement after construction. The design is to determine either surcharge pressure (P_s) required to ensure that total settlement is define under final pressure (P_f) within the given length of time or to determine the length of time required to achieve a given settlement under a define surcharge load.Mitchell adds that the consideration of primary consolidation and secondary compression is advisable to be considered separately due to time consuming for the secondary compression to be achieved. Formula of settlement at any time is expressed as following:

$$S_t = S_i + \bar{U}S_{cons} + S_s \qquad [Eq\ 2.1]$$

where;

S_t	=	Settlement at time t
S_i	=	Immediate settlement
$\bar{U}$	=	Average degree of consolidation
S_{cons}	=	Final consolidation settlement
S_s	=	Secondary compression settlement

In order to determine the time rate of settlement for primary consolidation in one-dimensional can be determined using Terzaghi theory and Hien (2008) cited that Terzaghi's Theory assumes that:

1. Soil particles and water is incompressible
2. Compressible layer is saturated, homo
3. Compression and flow of pore water pressure are vertical only
4. Strain because of within range of elasticity and external load is small
5. Using Darcy's Law for all hydraulic gradient
6. All consolidation parameters remain constant throughout consolidation process which are coefficient of compressibility, m_v, coefficient of permeability, k and coefficient of consolidation c_v.
7. A relationship between time, void ration and effective stress.

Furthermore, Figure 2.2 shows the stress vs time and settlement vs time relationships for a soil layer under stress increase P_f which in the ignorance of secondary compression (Mitchell, 1981). By referring to the graph shown in the Figure 2.2, if the surcharge load had been applied as the additional stress P_s, hence the settlement could be faster, and construction can be carried out by knowing that the settlement would not happen during and after construction.

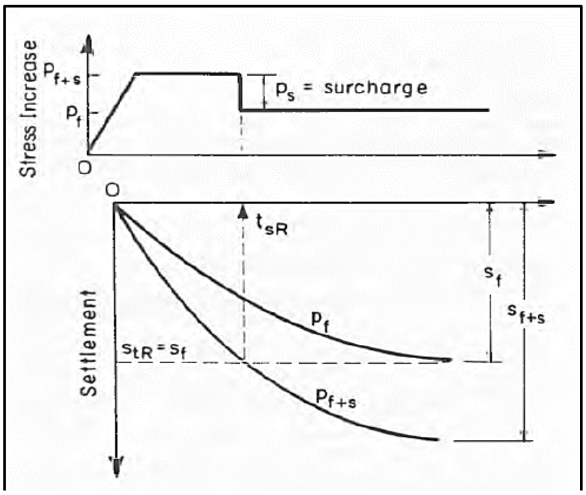


Figure 2.2: Primary Compression Using Surcharge Loading

Figure 2.3 shows the distribution of effective and excess pore water pressures before and after the application of surcharge being removed for a clay layer drained at both boundaries which had been discovered and studied by Aldrich (1965) and Johnson (1970).Furthermore, some portion of the layer may undergo further consolidation after the removal of surcharge, thus an additional consolidation in the center portion may be important, therefore to eliminate the further primary consolidation, the surcharge should be left until the pore pressure is at the most critical point, where can be determine using consolidation ratio ($\bar{U}_z$) as following:

$$(\bar{U}_z)_{f+s} = \frac{P_f}{P_f + P_s} \qquad [Eq\ 2.2]$$

where;

$\bar{U}_z$	=	Consolidation ratio
P_s	=	Surcharge pressure
P_f	=	Final pressure (expected to be achieved)

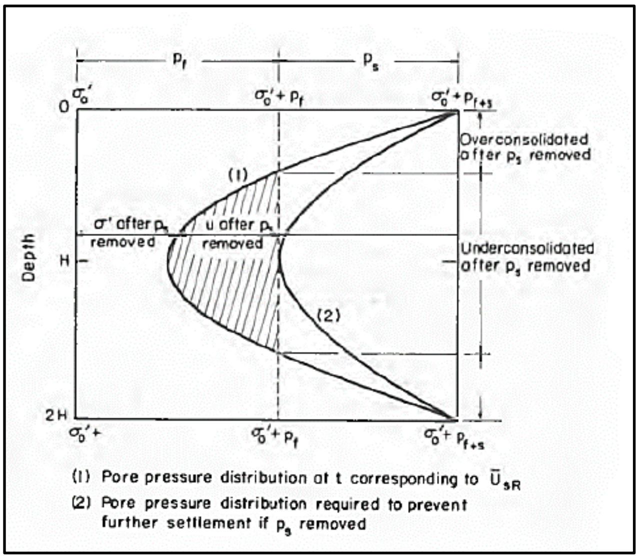


Figure 2.3: Pore Pressure Distribution After the Removal of Surcharge Load at Time, t_{SR}

In practice, the time for surcharge removal was determine based on the construction schedule, even though, the time to reach a certain percentage of the expected settlement is determined by using the following equation (Gofar and Mohamed ,2008):

$$t = \frac{0.197\, {H_d}^2}{C_v} \qquad [Eq. 2.3]$$

where;

C_v	=	Coefficient of consolidation
H_d	=	Drainage path (usually ½ of sample)
t	=	Time to reach certain percentage

Furthermore, the primary consolidation settlement is determine using the following equation:

$$S_c = C_c \frac{H}{1 + e_0} \log \frac{\sigma'_0 + \Delta\sigma'}{\sigma'_0} \qquad [Eq. 2.4]$$

where;

$C_c / 1 + e_0$	=	Compression ratio (CR)
σ'_0	=	Initial effective stress
$\Delta\sigma$	=	Stress increment
H	=	Thickness of compressible layer

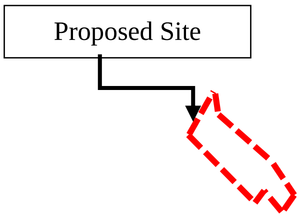
The application of this preloading method had not been alone adopted in building, storage tanks, flood control structure and airfield project, where this method is commonly being applied for project that directly connected to highways said Kirsch and Bell (2013).

3. Methodology

3.1.Site Location

Each construction area has their own unique soil properties. For this project the original ground is essentially a mangrove tidal swamp land, in addition, during high tide the site is usually submerged under water while at low tide the ground will appears with some portions with waterlogged. Figure 3.1 (a) shows the original ground site view after tree cutting.

(a) 



(b)

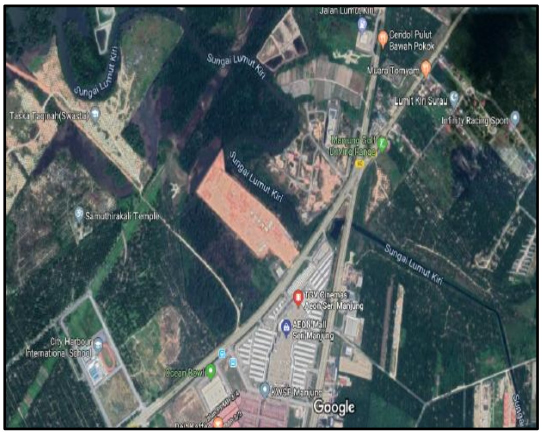


Figure 3.1:(a) Swampy Original Ground of Proposed Site (b)Proposed Site (Source: Google Maps, 2018)

The proposed site is set to build housing development with facilities such as multipurpose hall, mosque and shoplots on 14.88 acres of land. The location coordinates of this development are 04.22132^0 N and 100.670804^0 E. The proposed site is allocated beside of river known as Sungai Lumut Kiri which the site is at risk of flooding where based on data given by JabatanPengairandanSaliran (JPS) Manjung, the high tide level is 3.3m around month of October to November, therefore, the proposed platform for this project is at 3.5m for road level and 3.7m is set for building level. Figure 3.1 (b) shows the Google Map of the proposed site that is highlighted in red, the amenities available around the site are Aeon Shopping Mall, Manjung Golf Driving Range, Samuthirakali Temple, City Harbour International School, KSWP Manjung Office, Lumut Kiri Surau and few of food and beverages shop, either fast food or cafes.

3.2 Site Investigation Report

The report is produced by data collection from soil investigation for Proposed PPAM Development on Lot 52397 (PT 16636), MukimLumut, Daerah Manjung, Perak DarulRidzuan on 14.8 acres of land. The objectives of the investigations are to determine the subsoil conditions and to obtain soil data for the design purposes. The field work took about one month to complete which is started on 13.12.2017 and completed on 17.01.2018. A total of 6 Boreholes, 16 Mackintosh Probes and 2 Standpipe were carried out at a various location as showing in Figure 3.3, where the locations are indicted by Project Engineer and full site investigation layout plan is attached at Appendix. Furthermore, the machines and equipment that were used during the investigation were YWE D90R Rotary Drill, Mackintosh Set and Standpipe Set, which the Code of Practice of drilling is according to procedures outlined in BS5930:1999.

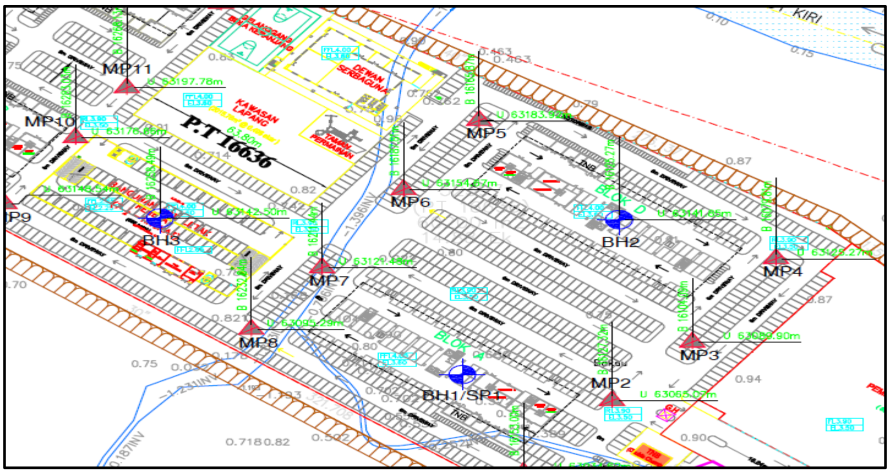


Figure 3.3: Portion of Site Investigation Layout Plan

3.3 Scope of Work

Scopes of work for this site investigation are:

1. Carry out wash boring at 6 Boreholes positions. In addition, perform undisturbed sampling in soft cohesive soil and Standard Penetration Test in stiff to hard cohesive soil and cohesionless soil.
2. Carry out 16 Mackintosh Probing locations at depth of not more than 15m below existing ground or where the condition of blows per 0.3m penetration is encountered.
3. Carry out 2 standpipes installation.
4. Carry out laboratory test on selected samples.

3.4 Field Test

The field tests conducted are included rotary wash boring, standard penetration test, mackintosh probes and standpipe.

3.5 Soil Parameter Data

The following tabulation showing the summary results of the test and analysis of proposed development in order to determine the soil parameter. Table 3.1 shows the borehole log soil parameter data such the reduced level, water level, final depth until reach the hardcore and standard penetration number (SPT 'N'). Then, Table 3.2 is summary of moisture content tested which is summarized into highest and lowest percentage of moisture content based on depth. The sample of water for each borehole are tested in terms of chloride content and sulphate content that is shown in Table 3.3. Percentage of soil material for each borehole is shown in Table 3.4 below which divided into gravel, sand, silt and clay material. Table 3.5 shows the result summary of Mackintosh Probe reading at 400 number of blows.

Table 3.1: Borehole Log Soil Parameter Data

Borehole No.	Reduced Level	Water Level	End Depth	SPT 'N'
BH1A	0.638m	0.10m	60.45m	25blows/120mm
BH2	0.626m	1.10m	60.45m	27blows/120mm
BH3	1.168m	0.10m	60.45m	27blows/120mm
BH4	0.129m	Full	60.45m	28blows/120mm

BH5	0.426m	0.25m	60.45m	25blows/120mm
BH6	0.693m	Full	60.45m	28blows/120mm

Table 3.2: Laboratory Test Result on Moisture Content

Borehole No.	Sample No.	Depth	Moisture Content
BH1A	D31	46.50m	11%
	D20	30.00m	32%
BH2	D24	36.00m	6%
	D2	3.000m	38%
BH3	D31	49.50m	9%
	D2	6.000m	257%
BH4	D24	37.50m	4%
	D6	10.50m	47%
BH5	D24	37.50m	8%
	D12	19.50m	33%
BH6	D14	24.00m	9%
	D7	13.50m	35%

Table 3.3: Chemical Test Result Summary on Water Sample Collected

Borehole No.	Chloride Content (mg/L)	Sulphate Content (mg/L)
BH1A	26	20
BH2	19	18
BH3	26	20
BH4	23	17
BH5	21	17
BH6	24	19

Table 3.4: Summary Analysis of Different Soil Type by Mechanical and Hydrometer Analysis

Borehole No.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BH1A	0	98	46	3
BH2	0	93	59	4
BH3	0	93	55	3
BH4	0	97	75	9
BH5	0	98	71	4
BH6	0	95	74	10

Table 3.5: Mackintosh Probe Reading Summary

Position No.	Reduced Level	Final Depth	Water Level
MP1	0.094m	10.66m	0.30m
MP2	0.516m	11.22m	0.30m
MP3	0.706m	10.95m	0.29m
MP4	0.958m	10.02m	0.30m
MP5	0.524m	10.34m	0.30m
MP6	0.176m	10.06m	0.30m
MP7	0.287m	9.76m	0.30m
MP8	0.501m	9.15m	0.30m
MP9	0.593m	10.71m	0.21m
MP10	0.577m	9.75m	0.25m
MP11	0.535m	10.05m	0.28m
MP12	0.348m	10.38m	0.28m
MP13	1.450m	10.94m	0.40m
MP14	0.929m	11.29m	0.40m
MP15	0.763m	10.06m	0.30m
MP16	0.465m	9.73m	0.47m

4 Results and Analysis

4.2 Project Site Details

The case study is based on project of mix development. The area of study is the whole 14.88 acres of land. With referring to the site investigation report, the average thickness of silty sand is 7.0 m while the average fill thickness is 1.9m thick. The thickness of surcharge to be applied on the surface of the ground to form a platform is 200mm thick. Figure 4.1 shows the cross-section of embankment with subsoil profile.

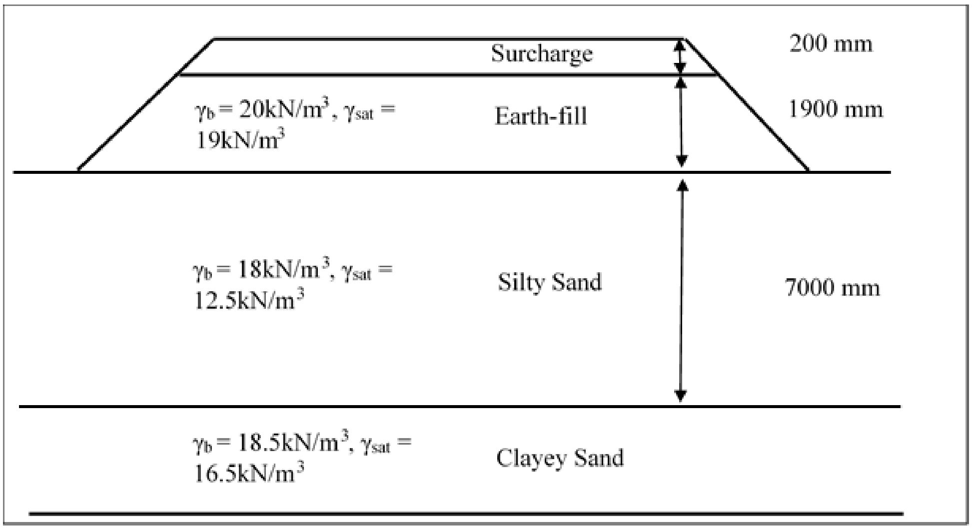


Figure 4.1: Cross-section of Embankment with Subsoil Profile

4.3 Modelling the Case Study

Table 4.1 shows the soil parameters data that are used in the GEO-5 settlement software. The soil permeability chosen for analysis was referring to the Table 4.2 below where it based on Swiss Standard SN 670 010b (1986).The coefficient of permeability for the silty sand based on the table is *3.00E-07,* the clayey sand is *5.50E-08* and for fill which is well graded sand as *1.00E-07*.The coefficient of consolidation value of $c_v = 0.026\ m^2/year$. Furthermore, the analysis is performed in two ways which are with application of surcharge that is *4 kPa* and without application of surcharge.

Table 4.1: Soil Parameters used in the Analysis

Parameter	Symbol	Value	Unit
<u>*Silty Sand*</u>			
Poisson's ratio	v	0.30	-

Unit weight	γ	18.0	kN/m^3
Deformation modulus	E_{def}	10	MPa
Angle of internal friction	φ	29	□
Cohesion of soil	c	5	kPa
Coefficient of permeability	k	3.00E-07	m/day
Clayey Sand			
Poisson's ratio	v	0.35	-
Unit weight	γ	18.5	kN/m^3
Deformation modulus	E_{def}	8	MPa
Angle of internal friction	φ	27	□
Cohesion of soil	c	8	kPa
Coefficient of permeability	k	5.50E-08	m/day
Well Graded Sand			
Poisson's ratio	v	0.28	-
Unit weight	γ	20.0	kN/m^3
Deformation modulus	E_{def}	50	MPa
Angle of internal friction	φ	36.5	□
Cohesion of soil	c	0	kPa
Coefficient of permeability	k	1.00E-07	m/day

Table 4.2: Typical Value for Soil Permeability, *k*

Description	**USCS**	**Min *(m/s)***	**Max *(m/s)***	**Specific Value *(m/s)***
Well graded gravel, sandy gravel with little or no fines	GW	5.00E-04	5.00E-02	
Poorly graded gravel, sandy gravel with little or no fines	GP	5.00E-04	5.00E-02	
Silty gravels, silty sandy gravels	GM	5.00E-08	5.00E-06	
Alluvial sand and gravel	(GM)	4.00E-04	4.00E-03	
Clayey gravels, clayey sandy gravels	GC	5.00E-09	5.00E-06	

Well graded sands, gravelly sands with little or no fines	SW	1.00E-08	1.00E-06	
Very fine sand, very well sorted	(SW)			8.40E-05
Medium sand, very well sorted	(SW)			2.23E-03
Coarse sand, very well sorted	(SW)			3.69E-01
Poorly graded sands, gravelly sands with little or no fines	SP	2.55E-05	5.35E-04	
Clean sands (good aquifers)	(SP-SW)	1.00E-05	1.00E-02	
Uniform sand and gravel	(SP-GP)	4.00E-03	4.00E-01	
Well graded sand and gravel without fines	(GW-SW)	4.00E-05	4.00E-03	
Silty sands	SM	1.00E-08	5.00E-06	
Clayey sands	SC	5.50E-09	5.50E-06	
Inorganic silts, silty or clayey fine sands with slight plasticity	ML	5.00E-09	1.00E-06	
Inorganic clay, silty clays, sandy clays of low plasticity	CL	5.00E-10	5.00E-08	
Organic silts and organic silty of low plasticity	OL	5.00E-09	1.00E-07	
Inorganic silts of high plasticity	MH	1.00E-10	5.00E-08	
Inorganic clays of high plasticity	CH	1.00E-10	1.00E-07	
Compacted silt	(ML-MH)	7.00E-10	7.00E-08	

4.4 Settlement Analysis by Geo-5 Settlement Software with Preloading Application

Geo 5 settlement software is used to determine the settlement based on time dependent on the consolidations of soil by applying surcharge or embankments.Hence, the final result analysis shows the final settlement analysis when applying preloading is *0.171m* and degree of consolidation of *100%*.

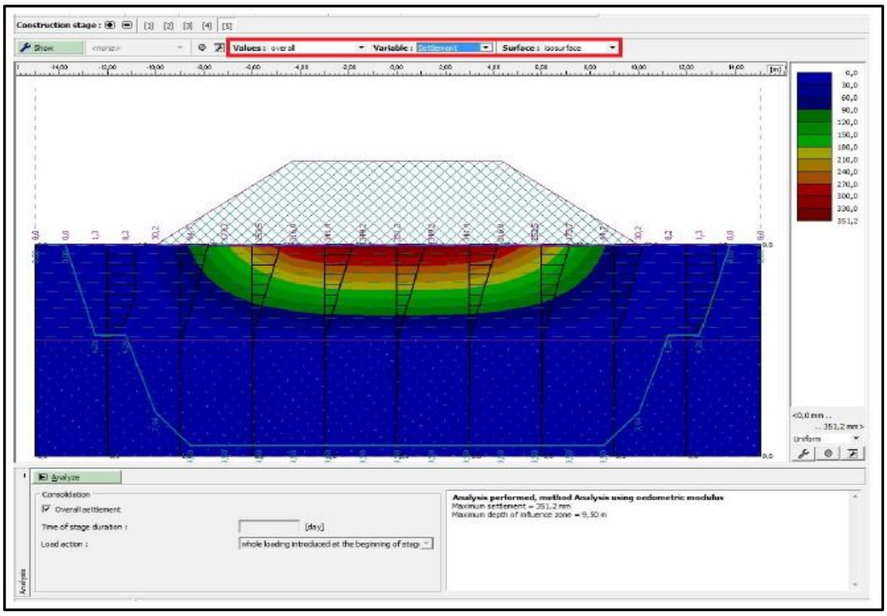
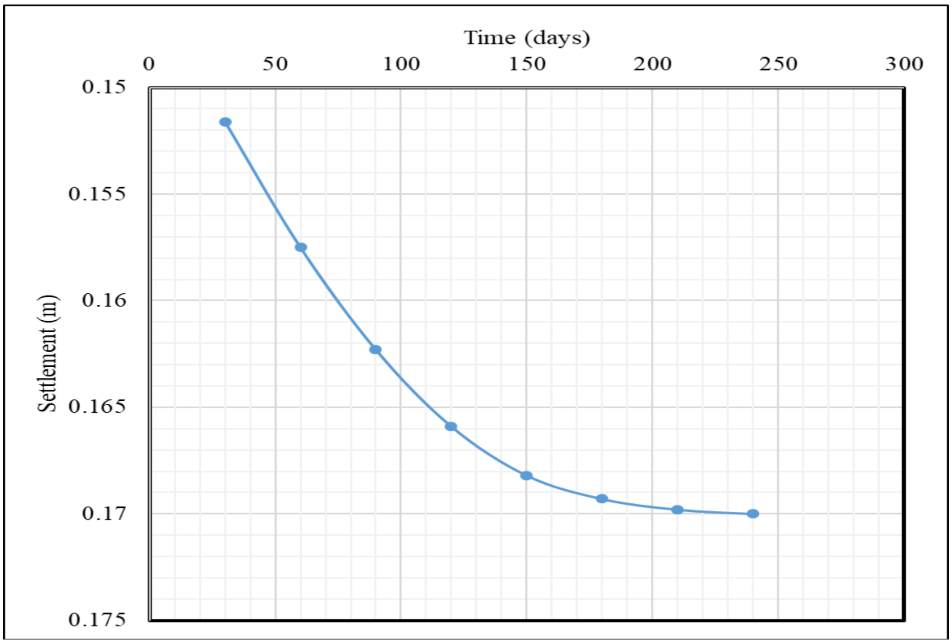


Figure 4.s: Modelling the case study by GEO-5 Software

Table 4.3 shows the settlement and degree of consolidation results according to the Geo 5 software. Referring to the Graph 4.1, the result of settlement of soil is increasing as the time increasing because settlement of soil will take place continuously. The result shows the settlement at 240 days when applying preloading with maximum settlement is *0.170m* at *99.7%* consolidation. It is noticed that with a time, the settlement of soils will keep on going until it reached the final consolidation which is 100% which according to analysis it will take about 260 days for this Manjung's site.

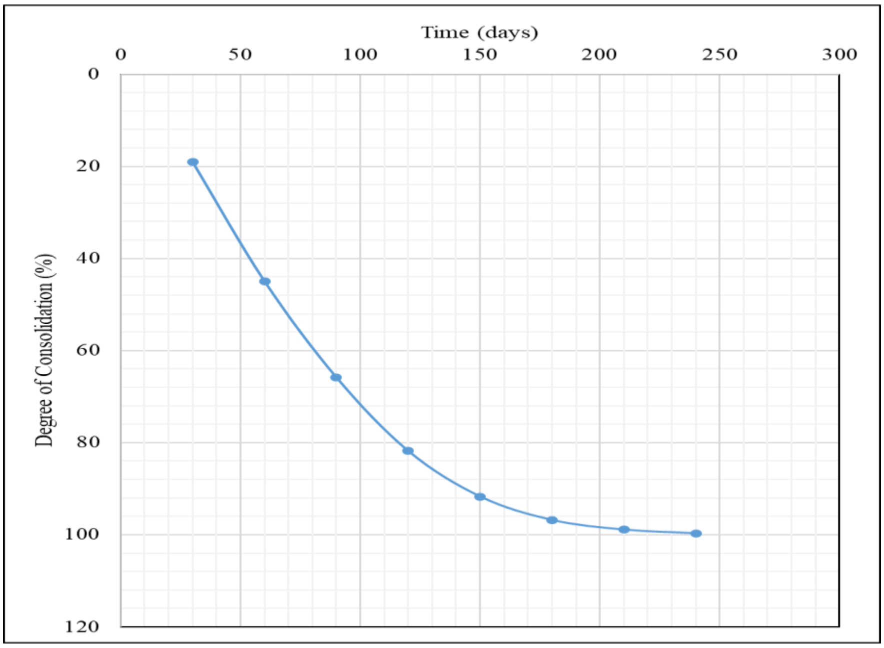
Table 4.3:Manjung's Analysis Results from Geo 5 Settlement Software with Preloading Application

Time (days)	Settlement (m)	Degree of Consolidation (%)
30	0.1516	19.0
60	0.1575	44.9
90	0.1623	65.8
120	0.1659	81.8
150	0.1682	91.7
180	0.1693	96.8
210	0.1698	98.9
240	0.170	99.7



Graph 4.1: Plotting Manjung's Settlement Result from Geo 5 Settlement Software with Preloading Application

Furthermore, Graph 4.2 below is showing the time versus degree of consolidation of chosen construction site based on the result obtained from Geo-5 settlement software when settlement and consolidation analysis was performed on soft soil with application of preloading.



Graph 4.2: Plotting Manjung's Consolidation Result from Geo 5 Settlement Software with Preloading Application

4.4 Settlement Analysis by Geo-5 Settlement Software without Preloading Application

The analysis is performed without application of preloading which to proof the theory that with application of preloading, the time taken to reach 100% consolidation is shorter. Data shows that the maximum settlement value without preloading will be *0.1548m* which take about *12,000days* to reach *100%* consolidation.Furthermore, analysis showing that at *240 days* the maximum settlement is *0.141m* with only *28.1%* of consolidation, whereas, when the application of preloading on the selected site, the degree of consolidation is almost reach to the *100%*, this is proof that the application of earth fill preloading will fasten the time of settlement and consolidation. Table 4.5 is the summary of settlement and degree of consolidation from the software analysis

Table 4.5:Manjung's Analysis Results from Geo 5 Settlement Software without Preloading Application

Time (days)	Settlement (m)	Degree of Consolidation (%)
30	0.1377	4.1
60	0.1382	6.8
90	0.1387	9.7
120	0.1392	12.8
150	0.1403	18.7
180	0.1408	21.7
210	0.1414	24.7
240	0.1421	28.6
365	0.1432	35.1
730	0.1483	63.3
5000	0.1526	87.9
10000	0.1548	100

5 Conclusion

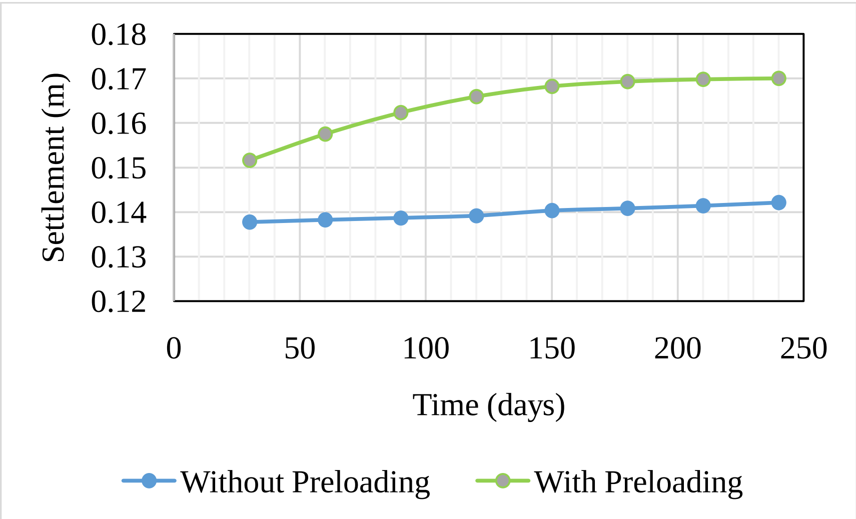
The comparison of embankment preloading performance in terms of settlement and degree of consolidation using oedometric modulus methods in 8 months after the application surcharge and without surcharge took place is tabulated in Table 5.1.

The ultimate settlement for the analysis with preloading gives result of *0.171m*, whereas without preloading the settlement is *0.155m* which this showing that the with application of preloading maximum value of settlement will be produced at only *260 days* of application, which to be compared with the without preloading, the ultimate settlement took about *12,000 days* to reach the *0.155m* settlement.

Degree of consolidation of analysis with preloading is 99.7% at 240 days whereas, at 240 days for the analysis without preloading is 28.6% only, where this proof that the theory of with application preloading on the soft ground as the soil stabilization will help to fasten the consolidation period. Thus, the site can continue with construction earlier.

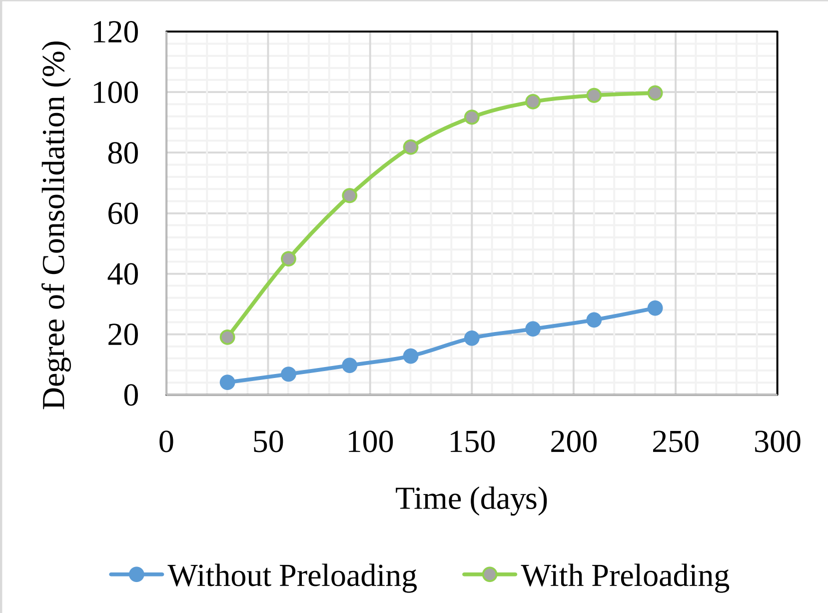
Table 5.1: The Comparison of Embankment Performance Verified by Settlement and Degree of Consolidation by using Various Method

Method Applied	**Ultimate Settlement *(m)***	**Settlement to Date of 240 days *(m)***	**Degree of Consolidation *(%)***
Geo 5 Settlement Analysis Software (with preloading)	0.171	0.170	99.7
Geo 5 Settlement Analysis Software (without preloading)	0.155	0.142	28.6



Graph 5.1: Settlement with Time for Various Embankment Conditions

Graph 5.1 shows the comparison of the settlement for embankment on soft soil based on different method applied on embankment versus time. The graph shows that without preloading the settlement per time is slow to be compared when application of preloading which the settlement happens faster. Therefore, the application of preloading can help to stabilize the soft soil faster and then, construction can begin earlier.



Graph 5.2: Degree of Consolidation with Time for Various Embankment Conditions

Graph 5.2 shows the degree of consolidation with time for different application of method on embankment. The graph showing the with preloading the consolidation happens faster to be compared with when without preloading where the time taken to reach 100% is predicted to be 12,000 days. With the application of preloading the degree of consolidation to reach 100% will take about 260 days based on the analysis prediction in the Geo 5 Settlement software. This proven by when manually calculation by using Conventional Method, the Manjung's site will reach 100% consolidation is about 250 days.

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