POLITEKNIK UNGKU OMAR

ANALYSIS OF SUBGRADE GROUND IMPROVEMENT USING PLAXIS 2D

MUHAMMAD DANISH AQIL BIN SANUSI
01BCT20F3024

CIVIL ENGINEERING DEPARTMENT

SESSION 2 2022/2023

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MUHAMMAD DANISH AQIL BIN SANUSI
01BCT20F3024

A report submitted in partial fulfilment of the requirements for the award of the Degree of Bachelor of Civil Engineering Technology with Honours.

CIVIL ENGINEERING DEPARTMENT

SESSION 2 2022/2023

DECLARATION OF ORIGINAL AND OWNERSHIP

TITLE: **ANALYSIS OF SUBGRADE GROUND IMPROVEMENT USING PLAXIS 2D**

SESSION: **MAC 2023**

MUHAMMAD DANISH AQIL BIN SANUSI

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BIN SANUSI
(990421-08-7403)

…………………………………
MUHAMMAD DANISH
AQIL BIN SANUSI

In front of me, TS. DR. RUFAIZAL
BIN CHE MAMAT (800715-04-5065)
as project supervisor on date:

…………………………………
TS. DR. RUFAIZAL BIN CHE
MAMAT

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ABSTRACT

The ongoing construction of MRL East Coast Rail Link (ECRL) which a standard gauge double-track high-speed railways infrastructure connecting across northeast Peninsular Malaysia require a very high demand of land area for development. Railway construction on soft soil to extremely soft soil is frequently done due to lack of area for development. Soft soils are one of the major sources of engineering issues as this soil has high compressibility and porosity thus countermeasures against soft soil have become an important necessity in geotechnical issue. In the initial procedure of Ground Treatment of soft soil involving remove and replace method, sand has become key material as reinforcement blanket for the embankment. Sand consumption has increased worldwide, in part due to the growth of the world's population, increasing standard of living, and rapid urban expansion, hence the reason this raw material became very costly and limited. Therefore, the aim of this research is to verify waste material in quarry dust can replace sand in geotechnical software which is Plaxis 2D. Three objectives were achieved including determining material properties, designing model parameters, and analysing output result of Plaxis 2D to deduce a conclusion from the data. Five different models with various mixed ratios between quarry dust and sand were prepared in Plaxis 2D. The calculated model was then analysed under the scope of displacement and settlement produced in different points with different loads. A model consisting of 25% sand and 75% quarry dust was deduced as the suitable model as the data provide lowest amount of settlement and average amount of displacement occurred. Under Finite Element Method calculations of Plaxis 2D, quarry dust can indeed coexist with sand to reduce the usage of this raw material globally.

KEYWORDS: Sand, Quarry Dust, Plaxis 2D, Settlement, Displacement, Subgrade.

ABSTRAK

Pembinaan berterusan ‘MRL East Coast Rail Link’ (ECRL) yang mana infrastruktur kereta api berkelajuan tinggi dan landasan berkembar yang menghubungkan lintasan timur laut Semenanjung Malaysia amat memerlukan permintaan kawasan tanah yang sangat tinggi untuk pembangunan landasan tersebut. Pembinaan kereta api di tanah yang lembut hingga tanah yang sangat lembut sering dilakukan kerana kekurangan kawasan pembangunan. Tanah lembut adalah salah satu sumber utama masalah kejuruteraan kerana tanah ini mempunyai kebolehmampatan dan keliangan yang tinggi sehingga berlakunya tindakan balas drastic terhadap tanah lembut. Perkara ini telah menjadi isu penting dalam masalah geoteknik. Dalam prosedur awal rawatan tanah lembut yang melibatkan kaedah membuang dan mengganti, pasir telah menjadi bahan utama sebagai selimut tetulang untuk subgred tanah. Penggunaan pasir telah kian meningkat di seluruh dunia, sebahagiannya disebabkan oleh pertumbuhan penduduk dunia, peningkatan taraf hidup, dan peningkatan bandar yang pesat, oleh itu bahan mentah seperti pasir ini telah menjadi sangat mahal dan terhad. Seterusnya, tujuan penyelidikan ini adalah untuk mengesahkan bahan buangan yang tidak lagi diguna pakai seperti debu kuari dapat menggantikan pasir dalam perisian geoteknik yang dikenali sebagai Plaxis 2D. Tiga objektif dicapai termasuk menentukan sifat bahan, merancang parameter model, dan menganalisis hasil output dari Plaxis 2D untuk menyimpulkan kesimpulan dari data yang diperolehi. Lima model berbeza dengan pelbagai nisbah campuran antara debu kuari dan pasir disediakan dalam Plaxis 2D. Model yang dikira kemudian dianalisis di bawah skop kadar anjakan dan penempatan tanah yang dihasilkan melalui koordinat titik yang berbeza berserta beban yang berbeza. Model yang terdiri daripada 25% pasir dan 75% debu kuari disimpulkan sebagai model yang paling sesuai kerana data memberikan jumlah penempatan terendah dan anjakan yang hampir sama dengan berlaku di dalam subgred tanah ini. Di bawah pengiraan perisian Plaxis 2D ini, dapat disimpulkan bahawa debu kuari sememangnya dapat wujud bersama pasir untuk mengurangkan penggunaan bahan mentah laitu pasir secara global.

KATA KUNCI: Pasir, Debu Kuari, Plaxis 2D, Penempatan, Anjakan, Subgred.

LIST OF CONTENT

CHAPTER	CONTENT	PAGE
	DECLARATION OF ORIGINAL AND OWNERSHIP	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF ABBREVIATION	xiv
1	**INTRODUCTION**	1
	1.1. Introduction	1
	1.2. Problem Statement	4
	1.3. Research Objectives	5
	1.4. Scope Of Study	6
	1.5. Significance Of Study	8
	1.6. Expected Outcomes	8
	1.7. Conclusion	9
2	**LITERATURE REVIEW**	10
	2.1. Introduction	10
	2.2. Material	10
	2.2.1 Geotextile	10
	2.2.1.1. Non-Woven Geotextile	12
	2.2.1.2 Woven Geotextile	13
	2.2.2 River Sand	14
	2.3. Waste Material	15
	2.3.1. Quarry Dust	16
	2.4. Physical Properties of Comparison	18

	2.4.1	Specific Gravity	21
	2.4.2	Water Absorption	22
	2.4.3	Moisture Content	23
	2.4.4	Fineness Modulus	24
	2.4.5	Bulk Density	25
	2.4.6	Particle Size Distribution	26
	2.5	Industrial Revolution 4.0	28
	2.6	Internet of Things	29
	2.7	Finite Element Method	31
	2.8	Plaxis 2D	32
	2.9	Conclusion	34
3	**METHODOLOGY**		35
	3.1	Introduction	35
	3.2	Analysis Process	35
	3.3	Analysis Framework	35
	3.4	Problems Discovery	36
	3.5	Data Collection	37
	3.6	General Purpose in Plaxis 2D	37
	3.7	Plaxis 2D Input (Pre-Process)	38
	3.8	Plaxis 2D Output (Post-Process)	42
	3.9	Geometry Model	43
	3.10	Material Properties	46
	3.11	Construction Analysis	51
	3.12	Conclusion	53
4	**DATA ANALYSIS**		54
	4.1	Introduction	54
	4.2	Subgrade Analysis	54
	4.3	Total Displacement Data	56
	4.4	Analysis of Displacement Data at Point Z	62
	4.5	Total Settlement Data	64
	4.6	Analysis of Settlement Data at Point X	71
	4.7	Analysis of Settlement Data at Point Y	72
	4.8	Conclusion	74

5 DISCUSSION, RECOMMENDATION AND CONCLUSION 75

5.1 Introduction 75

5.2 Discussion 76

5.3 Conclusion 77

5.4 Recommendation 77

LIST OF TABLES

TABLE NUMBER	TITLE	PAGE
Table 2.1	Standard properties of non-woven geotextile	12
Table 2.2	Standard properties of woven geotextile	13
Table 2.3	Properties of river sand	14
Table 2.4	Previous studies on the use of quarry dust	17
Table 2.5	Physical Properties	18
Table 3.1	Plaxis 2D General Phase	37
Table 3.2	Soil Parameter 1	47
Table 3.3	Soil Parameter 2	48
Table 3.4	Geotextile Parameter	49
Table 3.5	Staged Construction Parameter	52
Table 4.1	Mix Ratios Used	55
Table 4.2	Thickness (mm) of Materials	55

LIST OF FIGURES

FIGURE NUMBER	TITLE	PAGE
Figure 1.1	Layout plan for The East Coast Rail Link (ECRL) located in Setiu, Terengganu as Section 3	6
Figure 1.2	Remove and Replace Method in Setiu, Terengganu	7
Figure 1.3	The usage of Sand in Remove and Replace	7
Figure 2.1	Placement of geotextile in soil treatment	11
Figure 2.2	Close look-up of non-woven geotextile	12
Figure 2.3	Close look-up of woven geotextile	13
Figure 2.4	Extraction of river sand on-site	15
Figure 2.5	Unused quarry dust available on-site	18
Figure 2.6	Graph mean value of specific gravity / relative density	21
Figure 2.7	Graph mean value of water absorption	22
Figure 2.8	Graph mean value of moisture content	23
Figure 2.9	Graph mean value of fineness modulus	24
Figure 2.10	Graph mean value of Bulk Density	25
Figure 2.11	Graph Particle Size Distribution of Sand	26
Figure 2.12	Graph Particle Size Distribution of Quarry Dust	27
Figure 2.13	Pie Chart of General Market Structure	31
Figure 2.14	Plaxis 2D Logo	33
Figure 2.15	Flow of Plaxis 2D	33
Figure 3.1	Analysis Framework	36
Figure 3.2	Logo in the Interface	38
Figure 3.3	Soil Mode	39
Figure 3.4	Soil Mode Interface	39
Figure 3.5	Logo in the Interface	39
Figure 3.6	Structures Mode	39
Figure 3.7	Structures Mode Interface	40

Figure 3.8	Logo in the Interface	40
Figure 3.9	Mesh Mode	40
Figure 3.10	Mesh Mode Interface	40
Figure 3.11	Logo in the Interface	41
Figure 3.12	Flow Conditions Mode	41
Figure 3.13	Flow Conditions Mode Interface	41
Figure 3.14	Logo in the Interface	41
Figure 3.15	Staged Construction Mode	42
Figure 3.16	Staged Construction Mode Interface	42
Figure 3.17	Example of calculation after pre-process	42
Figure 3.18	Example of Result in Plaxis 2D Output	43
Figure 3.19	Geometry Model (No Load)	44
Figure 3.20	Geometry Model (Line Load: 10kN)	44
Figure 3.21	Geometry Model (Point X: 0,0)	44
Figure 3.22	Geometry Model (Point Y: 3.5,0)	45
Figure 3.23	Geometry Model (Point Z: 7,0)	45
Figure 3.24	Completed Model in Plaxis 2D (No Load)	46
Figure 3.25	Completed Model in Plaxis 2D (Line Load)	46
Figure 3.26	General Properties of Sand in Plaxis 2D	50
Figure 3.27	Mechanical Properties of Sand in Plaxis 2D	50
Figure 3.28	Groundwater Properties of Sand in Plaxis 2D	50
Figure 3.29	All Seven Phases in Staged Construction	53
Figure 4.1	Analysis of Displacement in Model A with no load	56
Figure 4.2	Analysis of Displacement in Model A with load (10 kN)	57
Figure 4.3	Analysis of Displacement in Model B with no load	57
Figure 4.4	Analysis of Displacement in Model B with load (10 kN)	58
Figure 4.5	Analysis of Displacement in Model C with no load	59
Figure 4.6	Analysis of Displacement in Model C with load (10 kN)	59
Figure 4.7	Analysis of Displacement in Model D with no load	60
Figure 4.8	Analysis of Displacement in Model D with load	61

	(10 kN)	
Figure 4.9	Analysis of Displacement in Model E with no load	61
Figure 4.10	Analysis of Displacement in Model E with load (10 kN)	62
Figure 4.11	Graph of Displacement versus Models at Point Z with 0 kN	63
Figure 4.12	Graph of Displacement versus Models at Point Z with 10 kN	63
Figure 4.13	Analysis of Settlement in Model A with no load	64
Figure 4.14	Analysis of Settlement in Model A with load (10 kN)	65
Figure 4.15	Analysis of Settlement in Model B with no load	66
Figure 4.16	Analysis of Settlement in Model B with load (10 kN)	66
Figure 4.17	Analysis of Settlement in Model C with no load	67
Figure 4.18	Analysis of Settlement in Model C with load (10 kN)	68
Figure 4.19	Analysis of Settlement in Model D with no load	68
Figure 4.20	Analysis of Settlement in Model D with load (10 kN)	69
Figure 4.21	Analysis of Settlement in Model E with no load	70
Figure 4.22	Analysis of Settlement in Model E with load (10 kN)	70
Figure 4.23	Graph of Settlement versus Models at Point X with 0 kN	71
Figure 4.24	Graph of Settlement versus Models at Point X with 10 kN	72
Figure 4.25	Graph of Settlement versus Models at Point Y with 0 kN	73
Figure 4.26	Graph of Settlement versus Models at Point Y with 10 kN	74

LIST OF ABBREVIATION

MRT	Mass Rapid Transit
LRT	Light Rapid Transit
STAR	Sistem Transit Aliran Ringan
KTM	Keretapi Tanah Melayu
ETS	Electric Train Service
MRL	Malaysia Rail Link
ECRL	East Coast Rail Link
IR4.0	The Fourth Industrial Revolution
PTT	Pembinaan Tetap Teguh
DSM	Deep Soil Mixing
RNR	Remove And Replace
USM	Unsuitable Soil Material
SG / Sp. Gr.	Specific Gravity
CU	Coefficient Of Uniformity
CC	Coefficient Of Curvature
R&D	Research And Development
FEM	Finite Element Method
MC	Mohr-Coulomb
SSC	Soft Soil Creep

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Malaysia is experiencing a transitional phase into becoming one of the most develop infrastructure country across the globe. One of the main attractions of infrastructure available in this country is utilization of public transportation especially railway transportation. Railway transportation is one of the ways for public to reach their destination. There are a few organizations on railway business available in Malaysia such as MRT, LRT, STAR LRT, RapidKL, KTM and ETS. Although the nation lacks high-speed trains, ETS trains can travel at a top speed of 140 km/h but still designed to travel up to 160 km/h, making them theoretically a high-speed rail (Community, 2010).

It is undeniable that there has been rapid development of high-speed railways worldwide especially in Malaysia. Speed had always been an important factor for railways, and they constantly tried to achieve higher speeds to decrease journey times for passenger. Rail transportation in the late 19th century was not much slower than non-high-speed trains today, and many railways regularly operated relatively fast express trains which averaged speeds of around 100 km/h. The Tokaido Shinkansen, the world's first high speed rail system had begun operated since 1964 in Japan. The system is also known as 'Bullet Train' worldwide can travel up to 320 km/h. Several European nations such as France, Germany, Spain, Italy started to follow Japan's lead afterwards (Nunno, 2018).

In 2016, another huge project involving high-speed trains has been agreed between the Malaysian Government and China Communications Construction Company Ltd (CCCC) (Ibrahim & Jaipragas, 2018) which will be operating on 2027. This project indirectly complies with the 2030 Agenda for Sustainable Development which is adopted by all United Nations Member States in 2015 (Chan, 2019). By fulfilling among the 17 Sustainable Development Goals available such as Goal No. 9 and Goal No. 11 involving resilient infrastructure and sustainable cities, Malaysia can aim to bring balance between meeting the requirements of what the present demands while not overlooking the needs of future generations.

The ongoing construction of MRL East Coast Rail Link (ECRL) which a standard gauge double-track high-speed railways infrastructure connecting across northeast Peninsular Malaysia require a very high demand of land area for development. Railway construction on soft soil to extremely soft soil is frequently done due to lack of area for development (Kasim et al., 2013). Malaysia especially in urban coastal across northeast peninsular areas have many soft soils that are mainly composed of fine particles, such as clay and silt. Utilizing alluvial sites and soft soil such as soft clay which typically exhibits considerable stratification such as organic debris, seashells, and rotting wood has become crucial part to establish human societies in accordance with the rise of population growth.

According to Mamat et al. (2019), soft soils are one of the major sources of engineering issues that are derived from excessive settlement of the soil during and after construction phases as this soil have high compressibility and porosity. There have been numerous failures in the past that were caused by excessive settlement and deformation to structures because of low shear strength, high compressibility, and porosity of soft soil, both locally and worldwide. Thus, countermeasures against soft soil have become an important necessity in geotechnical issue (Rashid et al., 2017).

To build a construction such as high-speed railways infrastructure on soft ground require construction of an embankment. Robinson (2023) noted that an embankment is a man-made wall built to keep water back or to support a road, rail line, or canal. These man-made mounds mainly consist of stones, rocks, and earth. Most have sloping sides, much like small hills, and they're typically longer than they are tall. An embankment also is typically built by compacting earthen materials in place, so the compaction properties of soil (optimum water content and maximum dry density) are very important to performance. However, settlement issue can still occur even after the construction of the embankment is complete.

Various methods can be implemented to particularly treat soft soil as such by conducting ground treatment in subgrade is one of them. Subgrade is a critical component of railway systems as it provides a stable platform for the track substructure. The role of the subgrade in railways is like a building foundation. The applied loads are transferred by the deflection of the rail to the ballast bed and then passed on via the subgrade to the subsoil. It is important to prevent subgrade attrition, excessive plastic deformation, consolidation, progressive shear failure, excessive swelling, and shrinkage (Nie et al., 2016).

Famous ground treatment available for subgrade is remove and replace. According to Hamakareem (2020), remove and replace can be consider as one of the methods which is suitable for any soft or weak soil. This method also one of the earliest and simplest method to enhance the conditions of the bearing soil. Soft or weak soil such as organic soil or medium and soft clay can be replaced with competent materials such as sand, gravel, or crushed stone as well, nearly any soil can be used in fills. However, when utilised as a replacement layer, some soils are more challenging to compact than others. Under shallow foundations, replacement soil can be used to boost soil carrying capacity and lessen consolidation settlement. It has some benefits over other methods and deep foundations since it is more affordable and causes less development delay. Despite the benefits of replacing soil, the thickness of the replacement soil is determined by experience, which in many circumstances is questionable (Gaafer et al., 2015). Ground treatment as whole has many different approaches that can be implemented on soft ground.

In remove and replace of soft soil, sand play a key role in making sure the ground treatment is completed. As widely known, sand consumption has increased worldwide, in part due to the growth of the world's population, increasing standard of living, and rapid urban expansion (Gavriletea, 2017). This has led to mushrooming sand markets across the world, feeding the local to regional construction sectors of rapidly growing urban centres. Without sand and geotextile as geosynthesis product, soil failure such as excessive settlement, failure of sub structure which is lead to superstructure damage and many others failure will occur.

Raw material such as sand is mined more than any other mineral in the world. Roughly 40 billion to 50 billion tons of aggregate sand (including gravel and crushed rock) are extracted every year from the earth (Schiff, 2022). Until recently, sand has been mined predominantly from land quarries and riverbeds, but, due to intensive exploitation and because this practice has been banned in many regions and environmental regulations have become much stricter or no longer allow this, nowadays mining of river sand is increasing significantly. Sand mining may have direct or indirect effects on rivers. Direct effects are those in which the disruption of the ecosystem is caused directly by the elimination of a resource, such as the habitat in floodplains. Indirect effects are connected to ecosystem modifications that spread throughout the system because of physical modifications in the river system brought on by sand extraction (Koehnken et al., 2020)

1.2 PROBLEM STATEMENT

Since the train transportation can transport heavy freight over long distances at a lower cost and is environmentally beneficial, the railroad has become the preferred form of transportation because of population growth that causes extensive urbanization. In 2011, the human population reached seven billion, and since then the population continues to increase. Today, about 54% of the world's population is living in urban areas and it is assumed that by 2050 the percentage will reach 66% (Nations, 2014). Governments and companies will be under pressure to change the way they approach urban development because of both the ongoing global population expansion and the accelerating rate of urbanisation. Sand as raw material that is consistently used in this project is one of the sole reasons for this research to be conducted. Taking into consideration the fact that sand is an important resource for many industries and demand for different products will increase in the future, sand demand will also increase (Gavriletea, 2017). Thus, optimizing different substitute material for sand in existing building and infrastructure represent a sustainable step that can be made to reduce sand consumption. Recycled building and quarry dust material can be a suitable substitute for sand (UNEP, 2014).

Next, the performance of the railroad track structure depends in large part on the quality and support provided by the subgrade. The design of the subgrade is defined according to the type of traffic, bearing capacity of the subgrade, configuration of the track, climatic and hydro-geological conditions. Therefore, it is important for subgrade to be designed to show a good short- and long-term performance, resisting to failure and excessive deformation, respectively, induced by repeated loads. The subgrade is an integral part of the track constructions, and its characteristics have a big impact on the performance and quality of the railway track (Correia, 2021). This is due to the fact that modern high-speed rail systems are sensitive to environmental factors, including traffic loads and weather-related strains. The performance of railway infrastructures will be significantly impacted by such extreme weather events, in addition to the performance of traffic networks (Jiang et al., 2015). Thus, by having a proper material design for subgrade, any settlement failure can be avoided.

Moreover, the Fourth Industrial Revolution (4IR or Industry 4.0) describes the current state of the world's digital revolution, which causes the lines separating the physical, digital, and biological worlds to become hazier. This involves the development of technologies that have recently become even more available and less expensive. There are eight essential technologies that matter most for business today: artificial intelligence, augmented reality, Blockchain, drones, the Internet of Things (IoT), robotics, virtual reality and 3D printing. These technologies are creating opportunities for sustainability, growth, productivity, and efficiency in the built environment, and the economy relies upon their output (Careers, 2021).

The implementation of IoT in modern society nowadays is necessary especially in Engineering department. It can become concerning how some companies or senior management do not commit fully into IoT implementation given how big the status of the company or the project that was handled. This can only signal one thing which is immaturity of industry standards around IoT (Mukhopadhyay & Suryadevara, 2014). Thus, for achieving objectives of this study, IoT will be brought into use which in this case is Plaxis 2D. It will not only boost the construction pace but also assist the engineers in analysing the deformation and stability in proposed high-speed railway or in geotechnical engineering in general (Rosato, 2019).

1.3 RESEARCH OBJECTIVES

This study aims to simulate a model consisting of quarry dust as waste material to replace sand as raw material in remove and replace of ground treatment in Plaxis 2D. The data from given simulation will then be analysed. Few objectives have been prepared to achieve this aim:

I. To determine material properties for Plaxis 2D Model
II. To design appropriate Model parameters of Plaxis 2D
III. To analyze and compare output result of different models with various mix ratios in Plaxis 2D

1.4 SCOPE OF STUDY

The East Coast Rail Link (ECRL) is a proposed railway infrastructure project designed to improve connectivity between Peninsular Malaysia’s East Coast states (Kelantan, Terengganu, and Pahang) and the West Coast states (Negeri Sembilan, Selangor, and the Federal Territory of Putrajaya), which is currently only partially connected by rail. The railway will be used for both passenger and freight transportation. The journey from Kota Bharu, in the north end of the rail line, to Gombak, the last few stations of the rail in the south, will take less than four hours as compared to seven hours by road. In addition to improved connectivity, the ECRL is intended to spur the development of the industrial, commercial, and tourism sectors along its route. A ground-breaking ceremony was held on August 9, 2017, to mark the start of construction. As of March 2021, 21.4 percent of the project had reportedly been completed. The rail line is scheduled to commence operation by 2027 (Khalid & Ikram, 2021).

Pembinaan Tetap Teguh (PTT) is one of the Malaysia's leading construction companies, specialized in Earthworks and Infrastructure works has been contracted to perform ground treatment on specified location marked by surveyor. The works performed include cut and fill of embankment, deep soil mixing (DSM) and especially remove and replace (R&R). Remove and replace can be consider as the main method this company to treat soft ground. Once depth of removal is confirmed in the drawing, geotextile separator and sand are placed before soil is lay as finishing level. Pembinaan Tetap Teguh (PTT) as a subcontractor for this project involve in ground treatment only.

Figure 1.1: Layout plan for The East Coast Rail Link (ECRL) located in Setiu, Terengganu as Section 3

In Pembinaan Tetap Teguh, as a Sub Contractor in Section 3 of Terengganu which is in Setiu, the company have been tasked to handle Ground Treatment area for East Coast Rail Link Project from Chainage 95 until Chainage 130 which is 35 KM long. This research will help the company to help reduce the cost of ordering sand or excessive mining of sand river that can bring negative impact to environment. By using quarry dust, a waste material in which has similar properties to sand can be applied to achieve similar and safe settlement compared to previous method. Geotextiles also will be applied as reinforcement in this railway embankments on soft soil by using layer-by-layer method.

Figure 1.2: Remove and Replace Method in Setiu, Terengganu

Figure 1.3: The usage of Sand in Remove and Replace

1.5 SIGNIFICANCE OF STUDY

By conducting this research, every company can know the different in result when substituting raw material which is sand with quarry dust. As scope of work is large for this railway project conducted by Pembinaan Tetap Teguh (PTT) which is 35km long, site engineer and supervisor involved will be able to benefit by knowing the impact of quarry dust on subgrade settlement without testing on-site which can be very dangerous. In fact, by using Plaxis 2D, the outcome data can be obtained straight away without wasting of time on-site. This can also indirectly lead working environment to raise awareness regarding implementation of Internet of Things (Iot) when handling software such as Plaxis 2D. If quarry dust can partially substitute sand depending on success fill ratio, then the company can already save costing for ordering sand which is very costly in today's market. Furthermore, obsession regarding sand mining can be reduce as it can damage the environment and cause harm to wildlife nearby. With the implementation of Plaxis 2D, companies can now cut down waste material on-site by simulating in the software which will make better business decisions and generate more revenue in the future. Finally, able to comply with the need of Industry 4.0 (IR 4.0) which extremely relevant and increasingly important for any organizations nowadays.

1.6 EXPECTED OUTCOMES

Every project including high-speed railway can be challenging but not for analysis of geotechnical. As Plaxis 2D provide fast computations, analysis of deformation and stability in Geotechnical Engineering or rock mechanics can be easily simulate. With the presence of quarry dust as proposed substitute material for sand, any settlement data can be simulated and analyse straight away. By using layer-by-layer method with different consumption rate of quarry dust, every outcome scenario can bring helpful information toward substituting of sand realistically in the future. If any outcome brings negative light toward the substitution of quarry dust as waste material in this ground treatment thus it safe to conclude that not all scope of work can be carried out by quarry dust. This waste material only suitable to be use in the mixing of concrete as sand replacement which originally why this material is famously known for.

1.7 CONCLUSION

In conclusion, the introduction, problem description, objective, and study scope are the four key parts of this analysis. This is the first chapter that explains the preliminary stages of the analysis in detail. This chapter provides detailed explanations of the problem description, in particular for the industrial-based issue with the usage of sand in particular as raw material involving ground treatment method in remove and replace. From the industrial problem, come out with three objectives for the study, which are to develop an analysis using Finite Element Method in Plaxis 2D. All of the objectives stated need to be comply which are to determine material properties for Plaxis 2D model, design appropriate model parameters of Plaxis 2 and lastly to analyse and compare output result of different models with various mix ratios in Plaxis 2D.

The scope of this analysis will be based on real chainage which act as referenced for given model to be created. The outcome and conclusion of this research will have beneficial impact towards the usage of sand while also benefits from quarry dust as alternatives to the former material. Moreover, by using Plaxis 2D which will help project manager and site engineers involved in geotechnical scope, it can indirectly lead working environment to raise awareness regarding implementation of Internet of Things (Iot) when handling software such as Plaxis 2D especially when the world right now is moving steadily towards Industrial Revolution (IR 4.0).

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Before conducting the analysis, understanding how the work of ground improvement involving one of the earliest and simplest on-site method in this project is very important. ECRL Section 3 based in Terengganu starts at Chainage 87+642.6 to Chainage 151+365.20. The total length of the railway alignment is 63.72km. Prior to forming of embankment over loose or soft ground, the soil over which fill material to be placed, where necessary, shall be improve. This will involve the stabilization of the soil below the embankment to improve the bearing capacity. This method statement is to describe ground improvement works by means of removal and replacement of unsuitable material.

2.2 MATERIAL

The material that will be used are shown in figures below. All these materials are essentials in remove and replace method of ground improvement. The quantity needed usually will be decided on site involving the area of excavation after removing Unsuitable Soil Material (USM).

2.2.1 GEOTEXTILE

Problems in construction are very common in the majority of areas in the Malaysia due to the various conditions of the soil. In such situations, polymers are frequently used as a major material to remedy the multiple complications caused by the soil or are used to maintain and preserve the desired soil conditions. Polymers, otherwise known as geosynthetics are fast growing family of geomaterials that are used in numerous civil engineering applications. Geotextiles are defined as permeable geosynthetics, which make up for the oldest and largest kind of geosynthetics.

There are four basic fundamental purposes of geotextiles, according to Iffah (2008). Which are:

I. Drainage

A geotextile functions as a drain when it collects a liquid and conveys it towards an outlet. Because textiles have a finite capacity, geocomposite drains were developed to provide a higher capacity. The geotextile, which regulates water flow into the drain, also serves as a filter to reduce drain capacity loss from soil obstruction. The drainage-in-the-plane is termed transmittivity as contrast to permittivity for filtration.

II. Filtration

A geotextile placed in contact with soil, allows water to pass while impeding soil particle mobility. Over the design life of the filtering application, both acceptable permittivity and soil retention are necessary.

III. Separation

In order to avoid the mixing of two distinct soils, a geotextile is positioned between them.

IV. Reinforcement

A geotextile is used to improve the mechanical properties of an earth structure by interacting with soil through interface shear.

The filtration and separation function of a geotextile has made it as the most probable method to help assist sand in settlement of remove and replace method involving soft soil treatment. As such, non-woven geotextiles and woven geotextiles are the two main varieties of geotextiles (Adajar, 2019).

Figure 2.1: Placement of geotextile in soil treatment

2.2.1.1 NON-WOVEN GEOTEXTILE

Non-woven geotextile or also known as low strength geotextile are created by binding the materials through chemical, heat, needle punching or other methods. It offers good filtration or drainage properties but low to medium strength and high elongation at failure. It also consists excellent water permeability, filterability, and durability, and may be widely applied to projects like railways, highways, and different projects (Taiwei, 2023). Due to their ability to allow moisture to pass through, non-woven geotextiles aren't as suitable for stabilization or reinforcement projects. Instead, they are best suited to applications concerning protection, drainage, separation, and filtration. A high-water permeability rate also means they do not lose strength over time, especially when used below ground. Besides, non-woven geotextiles are easier to cut, making them useful in certain industrial applications (Structure, 2020).

Table 2.1: Standard properties of non-woven geotextile

Author	Characteristic	Value
(Bourdeau, 1996)	• Thickness (mm) • Mass per Unit Area (g/m²) • Puncture Resistance (kN) • Tear Strength (kN)	0.6 261 0.4 0.4

Figure 2.2: Close look-up of non-woven geotextile

2.2.1.2 WOVEN GEOTEXTILE

Woven geotextile or also known as high strength geotextile are made by weaving together fabric on a loom and are relatively high in strength and stiffness tensile strength for stabilisation, erosion control, and aggregate separation. But it also has low elongation, relatively poor filtration, and drainage. Weaving films or threads together means these geotextiles are relatively impermeable, as such they are not very porous. As such, they are not ideal for drainage projects. Tensile stress makes woven geotextile the perfect fit for erosion control projects that do not involve draining and corrosion-resistant projects, and their very high load capacity makes them ideal for roads, airport runways, and parking lot construction. Moreover, it will resist UV degradation, making them suitable for long-term applications (Structure, 2020).

Table 2.2: Standard properties of woven geotextile

Author	Characteristic	Value
(Bourdeau, 1996)	• Thickness (mm) • Mass per Unit Area (g/m²) • Puncture Resistance (kN) • Tensile Strength (kN/m)	0.9 450 8.4 232

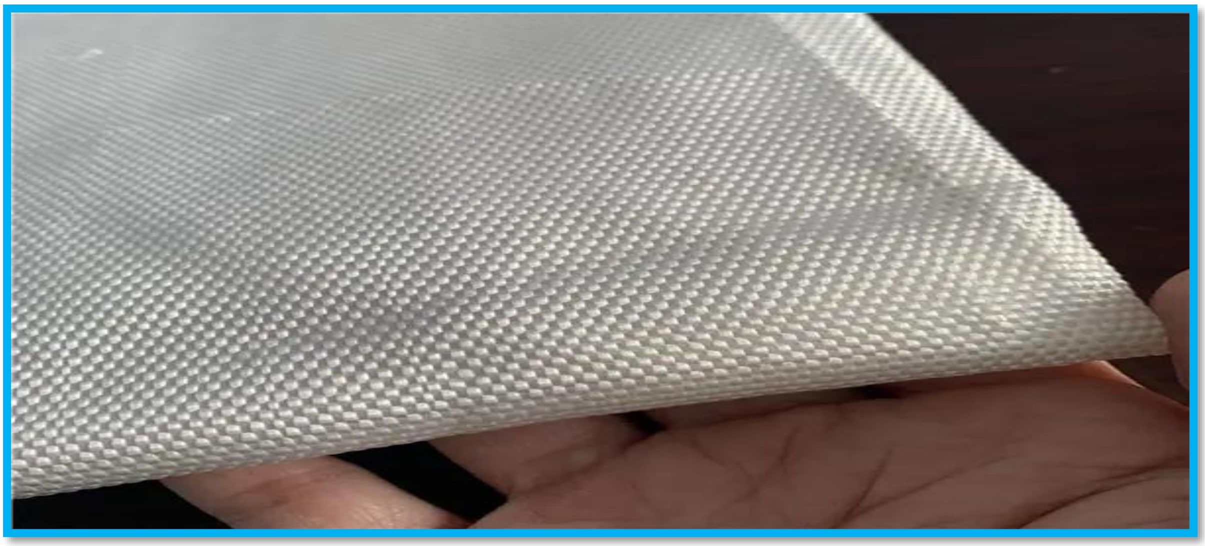

Figure 2.3: Close look-up of woven geotextile

2.2.2 RIVER SAND

Sand is a granular substance made up of tiny mineral fragments. The content of sand varies, but the grain size is what distinguishes it. Sand is coarser than silt and has smaller grains than gravel. A soil type or textural class that contains more than 85% of its mass in sand-sized particles is referred to as sand. Sand are important raw materials for any civil engineering work. In most cases, sand is usually used in concrete mixing worldwide. Thus, when there is slight issue regarding high demand of sand it can causes sudden increase in value. Company with prioritize organized costing management will not arbitrarily spend their money over excessive value of material available.

So, another method that can easily conducted and less costing is by having river sand mining. This method can have direct and indirect effects toward mined river. Direct effects are those in which the disruption of the ecosystem is caused directly by the elimination of a resource, such as the habitat in floodplains. Indirect effects are connected to ecosystem modifications that spread throughout the system as a result of physical modifications in the river system brought on by sand extraction. For instance, the channel, river hydraulics, or sediment budget of a river can be changed by material removal, which can then change the distribution of habitats and ecosystem functioning (Koehnken et al., 2020).

Thus, the most popular choice for a fine aggregate material in this treatment is natural river sand. The natural weathering of rocks over millions of years produces river sand. It is extracted from riverbeds. The loose, naturally occurring river sand is deposited with greater air voids. Due to the loose soil's propensity to either liquefy during earthquake vibrations or to densify and produce settlement under mechanical vibrations, building construction near rivers or in river basins poses a major risk. Natural river sand is utilised in this method of soft soil treatment.

Table 2.3: Properties of river sand

Author	Characteristic	Value
(Kanagarathinam et al., 2021)	• Coarse Sand (4.75-2.00mm) • Medium coarse sand (2.00-0.475mm) • Fine sand (0.475—0.075mm)	6.6% Weight 73.5% Weight 19.8% Weight

Figure 2.4: Extraction of river sand on-site

2.3 WASTE MATERIAL

By having an alternative solution to given issue is compulsory, which is why waste material is selected to conduct this research. Waste materials is a significant environmental issue and a hazard to the ecosystem. Reusing and discarding these resources are crucial. There are many attempts by many researches in finding the suitable material to be incorporating in this research as partial substitution for natural river sand. Among the wastes materials are metakaolin, rice husk, ground nut husk ash, volcanic ash, fly ash, slurry glass powder, marble dust powder, bamboo leaf ash, palm oil fuel ash and quarry dust (Hamid et al., 2018). Currently, quarrying operations are used extensively in the construction industry and are thought to be crucial for the growth of the economy in terms of supplying aggregates for concrete manufacturing (Leventakis et al., 2012).

Due to the release of dust into the atmosphere, water, and soil, quarrying had impacted the environment. The generated dust from the manufacture of aggregates must be used or recycled as trash in the building sector. Since then, the quarrying industry has had to deal with a serious environmental management challenge, which has prompted them to look for alternatives in evaluating the potential effects of their operation to meet the standards for waste disposal that specified by laws and regulations. It is beneficial for the quarrying and construction industry as the accumulated dust during aggregates production can be utilized as replacement for other materials.

The using of quarry dust as substitute material for sand can help to attain similar result while maintaining environment preservation. The implementation of quarry dust physically on-site as direct material substitute can bring various outcome without proper test beforehand, that will cause many unwanted casualties since this material will be substituting sand in remove and replace ground treatment of soft and weak soil. Thus, by having Internet of Things (IoT) instead as medium to simulate and calculate desired outcome can ease the hard work. Modern society nowadays had begun to move forward including with technology. Company with optimistic vision must implement IoT in their management in order to not be left behind with years passing by. This approach has found successful applications in the geotechnical monitoring field such as Plaxis 2D, with the integration of both traditional and innovative go-to finite element analysis application, can give more time when interpreting results data (Hemeda, 2022).

2.3.1 QUARRY DUST

Over the past ten years, the building industry has experienced rapid growth. Aggregate demand is rising as a result of the rise in concrete manufacturing. Waste products like fine quarry dust are produced at the same rate as urbanisation and industry. Quarry dust is crushed rock that is obtained from boulders of stone during the coarse aggregate production process (Naganathan et al., 2012). Quarry dust is another by-product of the crushing process used during quarrying operations. Malik et al. (2015) stated that among its numerous advantages is the preservation of the ecological equilibrium. Furthermore, it is employed in a variety of construction-related tasks, including the construction of roads and the production of building materials such lightweight aggregates, bricks, and tiles. Thus, it is used in place of sand to create concretes, which are said to be more robust and long-lasting than typical concrete materials (Gibson, 2016).

The quarry sand is the coarse fraction of the quarry powder and is being used as the fine aggregate in place of river sand concrete production (Leventakis et al., 2012). Even if sustainability has gained importance around the world, notably in the manufacturing of concrete, using these wastes appears to be a plausible attempt to be fulfilled. Additionally, when sand river mining is reduced, there may be less environmental exploitation. As an alternative to river sand that benefits concrete further, quarry dust has been suggested.

Quarry dust is special material as it is a non-porous material, it can be used right away, and it is less expensive than sand. It also can cause air pollution to the surrounding when spread across the atmosphere. Abdullah et al. (2018) state that one of the biggest issues the quarrying sector is currently dealing with is how to dispose of quarry dust. To use fewer natural resources, quarry dust should be used in the construction industry due to the lack of adequate trash disposal facilities and the escalating environmental concerns. Thus, dust disposal has become quite expensive. To enhance the physical, mechanical, and swelling qualities of the soil subgrade and subbase, quarry dust also had been used in the road pavement and utilised to make bricks and tiles and other building materials (Gautam et al., 2018). The dust was determined to be suitable for those procedures. Table 1 below presents previous studies conducted regarding sand replacement materials with quarry dust.

Table 2.4: Previous studies on the use of quarry dust

Author	Usage	Water-Cement Ratio/ Mix Ratio	Mixing Percentage
(Lohani et al., 2012)	Concrete Mix	0.55	0, 20, 30, 40 & 50
(Anya & Osadebe, 2015)	Sandcrete Mix	Mix Ratio: 1:6	0, 10, 20, 30, 40 & 100
(Kadir et al., 2017)	Fired Clay Brick	-	0, 10, 20 & 30
(Hani et al., 2019)	Concrete Brick Expand Polystyrene (EPS)	0.50	0, 20, 30, 40 & 50
(Chauhan & Bondre, 2015)	Concrete Mix	0.70	30, 40 & 50

Figure 2.5: Unused quarry dust available on-site

2.4 PHYSICAL PROPERTIES OF COMPARISON

Testing of material can be technically consider the last step in every construction process. Moreover, both the process and the material used will resulted in various outcome. Obviously, success is the desired outcome. If the material that goes into the product is defective and failed, then the outcome may also be defective and failed. When doing such simulation in this research understanding the material's properties can help to better predict the outcome data after the simulation. A property of material will aid detect variations in proposed research significantly (Schaulsohn, 2010).

Table 2.5: Physical Properties

Author	Material	Characteristic	Value
(Luhar et al., 2019)	Quarry Dust	• Specific Gravity / Relative Density • Water Absorption (%) • Bulk Density (kg/m³)	2.60 1.3 1750
(Febin et al., 2019)	Quarry Dust	• Specific Gravity / Relative Density	1.74

		• Water Absorption (%) • Bulk Density (kg/m³)	2.34 1550
(Elseknidy et al., 2020)	Quarry Dust	• Specific Gravity / Relative Density • Water Absorption (%) • Moisture Content (%) • Finite Modulus • Bulk Density (kg/m³) • Coefficient of Uniformity (Cu) • Coefficient of Curvature (Cc)	2.75 2.91 1.23 2.40 1730 6.75 1.13
	River Sand	• Specific Gravity / Relative Density • Water Absorption (%) • Moisture Content (%) • Finite Modulus • Bulk Density (kg/m³) • Coefficient of Uniformity (Cu) • Coefficient of Curvature (Cc)	2.64 1.11 1.14 2.32 1420 7.35 1.86
(Subbulakshmi & Vidivelli, 2014)	Quarry Dust	• Specific Gravity / Relative Density • Water Absorption (%) • Finite Modulus • Bulk Density (kg/m³)	2.83 1.50 2.46 1695

(Kapgate & Satone, 2013)	Quarry Dust	• Specific Gravity / Relative Density • Water Absorption (%) • Finite Modulus	2.50 0.50 2.90
(Opara et al., 2018)	Quarry Dust	• Specific Gravity / Relative Density • Finite Modulus • Bulk Density (kg/m³)	2.76 2.96 1360
	River Sand	• Specific Gravity / Relative Density • Finite Modulus • Bulk Density (kg/m³)	2.64 2.54 1570
(Meisuh et al., 2018)	Quarry Dust	• Specific Gravity / Relative Density • Water Absorption (%) • Moisture Content (%) • Finite Modulus • Bulk Density (kg/m³)	2.64 10.6 0.54 3.54 1650
	River Sand	• Specific Gravity / Relative Density • Water Absorption (%) • Moisture Content (%) • Finite Modulus • Bulk Density (kg/m³)	2.66 6.8 3.56 2.66 1600

2.4.1 SPECIFIC GRAVITY / RELATIVE DENSITY

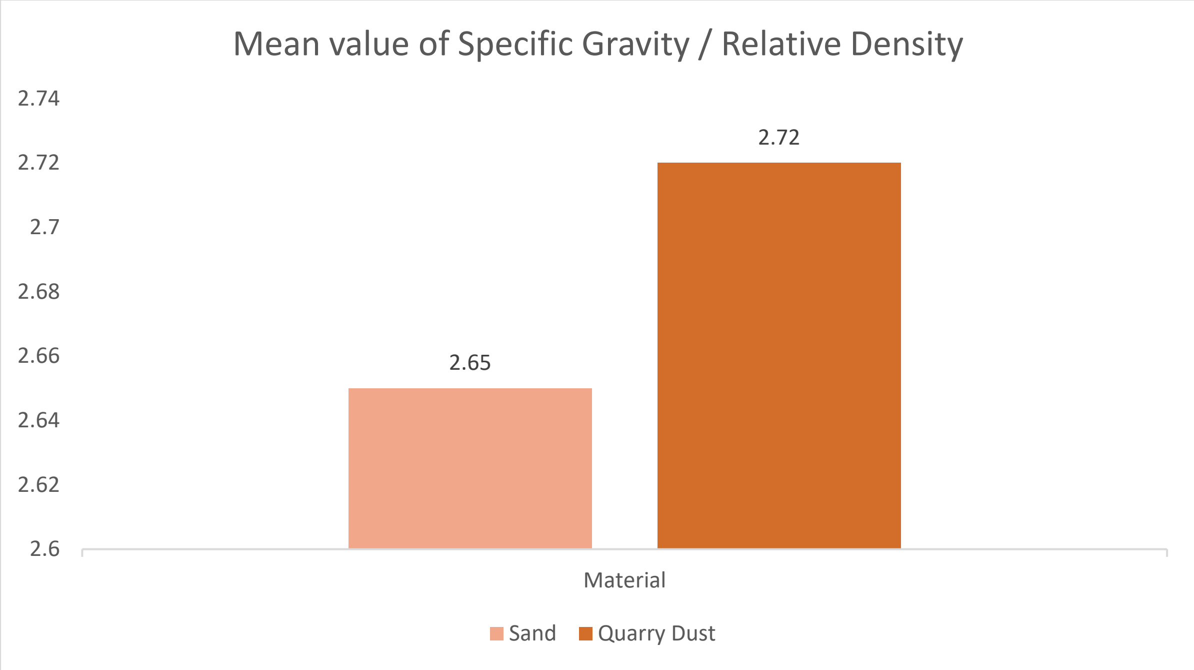

Figure 2.6: Graph mean value of specific gravity / relative density

Specific gravity, also referred to as relative density, is a measurement of a substance's density in relation to water's density. For solids and liquids, specific gravity is generally measured in relation to water at its densest state and for gases to room temperature air. It is given without units since it is a ratio. The abbreviation SG or Sp. Gr. stands for specific gravity. Specific gravity will show whether something will float or sink. Solids and liquids are measured against water, so if the specific gravity is less than one it will float, if it is higher than one it will sink. In geology and building, specific gravity has several applications as such to determine the soil's capacity to support loads by considering its specific gravity (Wright, 2022).

From Table 2.5, specific gravity of quarry dust can be considered in range from 2.50 until 2.80 which is within standard range of specific gravity involving soil. One low specific gravity of quarry dust which is 1.74 because the material is exposed to water or outside environment. Not much difference can be made between specific gravity of quarry dust and sand as both materials are in range of 2.60 and above.

Based on the ASTM D854 (Hosni et al., 2015), the range for type of soil which is sand is between 2.63 – 2.67 thus it can be deduced from table above that quarry dust in in the same bracket as sand in specific gravity or relative density proving minimal differences between them. Quarry dust is a material that compactible as the partial sand replacement material as the specific gravity of quarry dust is similar to the sand (Ying & Deraman, 2021).

2.4.2 WATER ABSORPTION

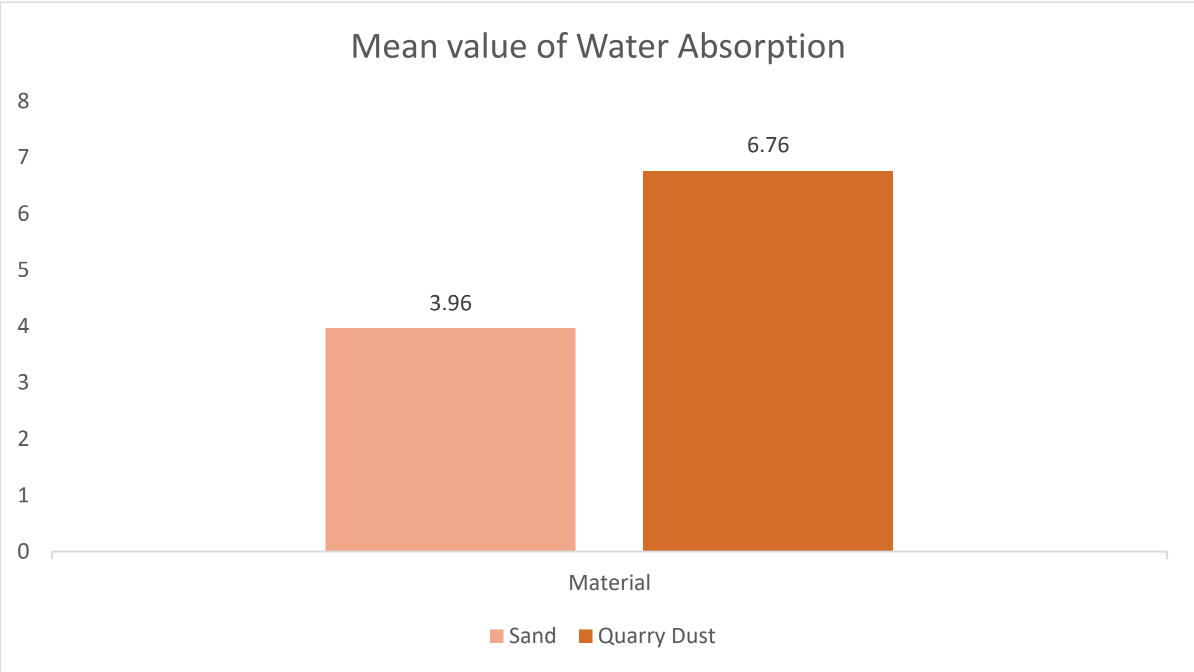

Figure 2.7: Graph mean value of water absorption

Water absorption rates are one of the most important measurements of material properties. Water absorption measures how much moisture a specific type of material is likely to absorb ongoing basis. Settlement failure will occur if the moisture penetration of the material used in it is too high. In general, if waste material such as quarry dust has a low water absorption, like porcelain material, the durability and strength will be higher (Behiels, 2019). Figure 2.7 above consist of percentage value of water absorption and comparison with river sand.

The value of water percentage in quarry dust is averaging around 1.7% until 2%. Water absorption for river is less than quarry dust proving durability and strength of quarry dust is below standards required due to amount of water absorb. For required standards that is acceptable, water absorption of unwashed sand is between 2.5– 3% whereas in washed sand the water absorption is between 2 – 2.5% (TechCenter, 2020).

2.4.3 MOISTURE CONTENT

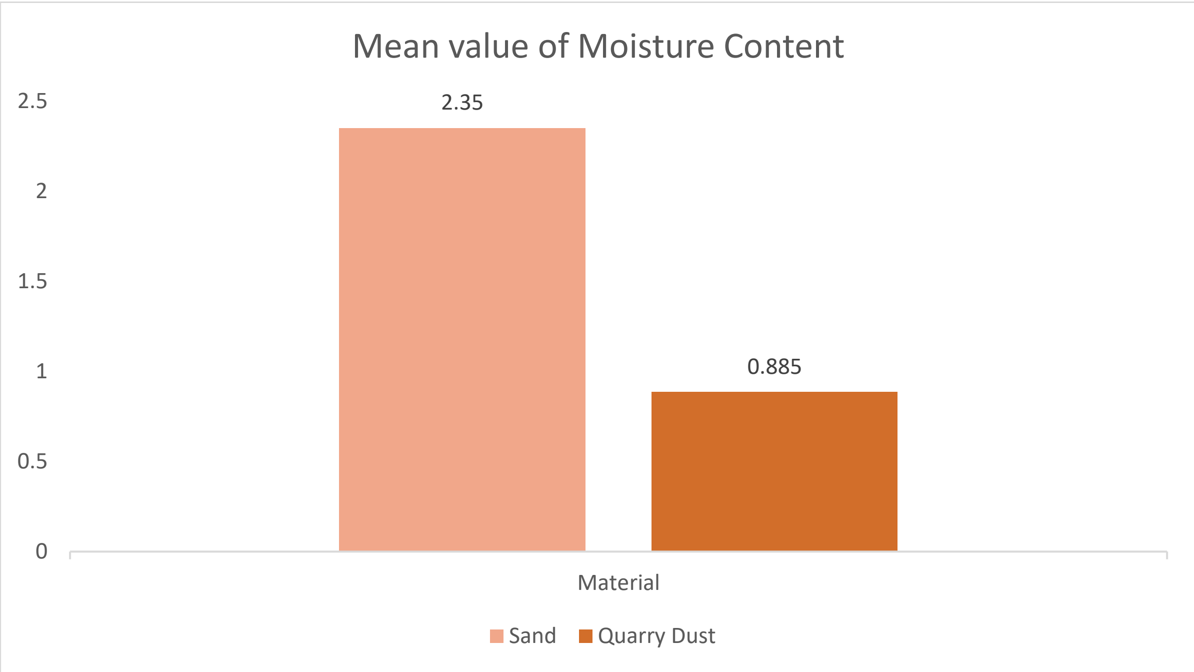

Figure 2.8: Graph mean value of moisture content

Moisture content is a parameter that can be used to describe the wetness of a material. The vapour phase of a liquid, notably water, is referred to as moisture. After condensation, moisture might appear either distributed within a solid or on a surface. The moisture content is often relatively low. A good example of moisture includes water vapour present in the air. For example, the moisture in soil occurs at internal surfaces and as capillary condensed water in small pores of the soil. Heat treatment methods is often used to determine the moisture content of soil samples.

These are called drying methods. Moisture content and water absorption are important analytical parameters that can be used to analyse different samples in chemistry. The key difference between moisture content and water absorption is that moisture content determines the amount of water vapour and other volatile components present in a sample, whereas water absorption determines the amount of water in a sample (Madhu, 2020).

The value of moisture content in quarry dust is averaging around 0.5% until 1.2%. While different researcher manages to get different outcome involving river sand, it is still important to note that maximum considerable percentage of sand that can be used on construction site is 5%. Moisture content less than 5% should be preferred for construction purpose.

With the increase of moisture content initially the volume of sand will also increase, but after certain time further increase in moisture can also results in decrease of volume (TechCenter, 2020). With the value of quarry dust not exceedingly even 2% signalling how similar the properties are to river sand.

2.4.4 FINENESS MODULUS

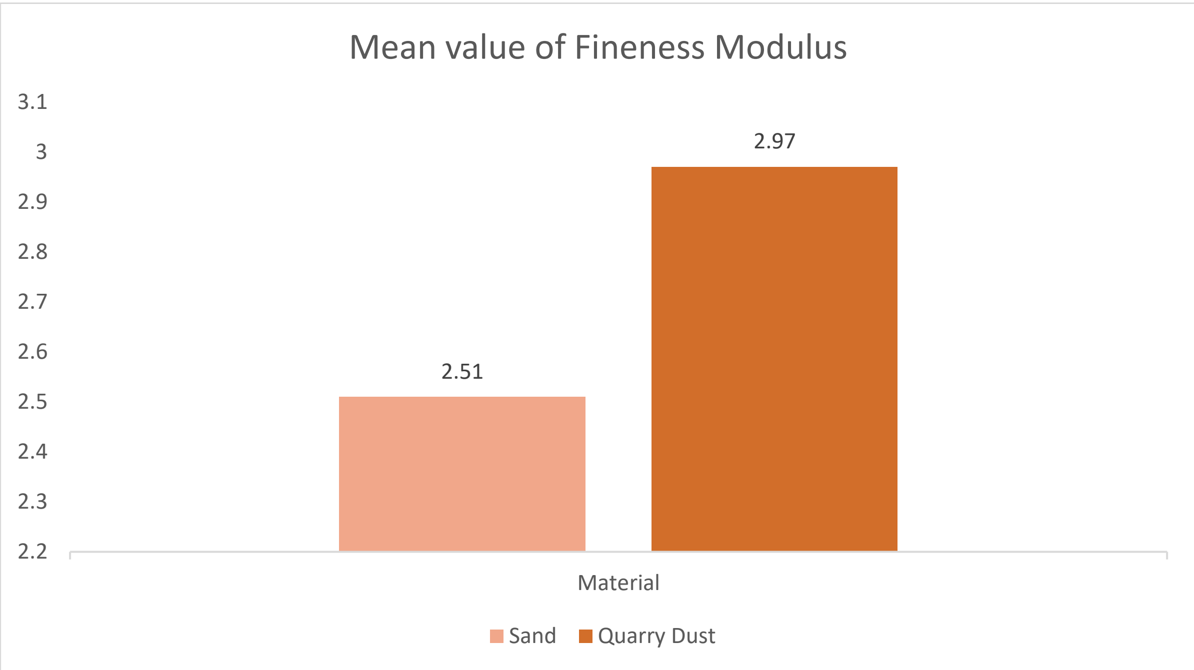

Figure 2.9: Graph mean value of fineness modulus

According to Suryakanta (2014), the Fineness Modulus (FM) is an empirical number that can be calculated by summing the percentages of aggregate samples that were retained on each of a given set of sieves, then divide the result by 100. Sieves are divided into sizes such as 150-µm (No. 100), 300-µm (No. 50), 600-µm (No. 30), 1.18-mm (No. 16), 2.36-mm (No. 8), 4.75-mm (No. 4), 9.5-mm (3/8-in.), 19.0-mm (3/4-in.), 37.5-mm (11/2-in.), and larger, increasing in the ratio of 2 to 1.

The same value of fineness modulus may therefore be obtained from several different particle size distributions. The purpose of fineness modulus is generally used to get an idea of how coarse or fine the aggregate is. More fineness modulus value indicates that the aggregate is coarser and small value of fineness modulus indicates that the aggregate is finer (Dhir et al., 2017).

The value of fineness modulus in quarry dust is averaging around 2.50 until 3.00. It is important to noted that fineness modulus of fine aggregate varies from 2.0 to 3.5mm. Fine aggregate having fineness modulus more than 3.2 should not considered as fine aggregate (Suryakanta, 2014). Thus, various researchers from table above had deducted that quarry dust and river sand do belong into fine aggregate category due to similar modulus range.

2.4.5 BULK DENSITY

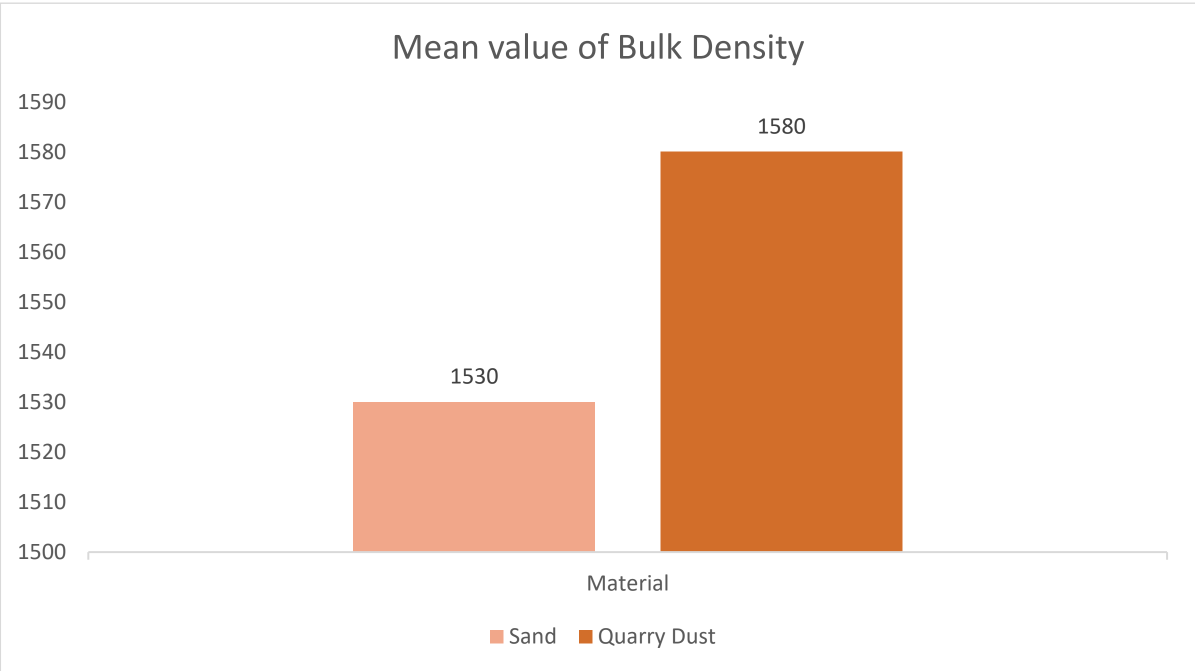

Figure 2.10: Graph mean value of Bulk Density

Bulk density is an indicator of soil compaction. It is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles. Bulk density is typically expressed in kg/m^3 (Mobilian & Craft, 2022). The total soil volume is the combined volume of solids and pores which may contain volume of air or volume of water, or both. Soil bulk density and porosity (the number of pore spaces) reflects the size, shape and arrangement of particles and voids belong in soil structure.

It can be seen from table above the value of bulk density in quarry dust is averaging around 1500 kg/m^3 until 1800 kg/m^3. Research above shows some value of bulk density in quarry dust can be higher than river sand. The approximate bulk density of sand that is commonly used in normal-weight concrete construction is between 1520 kg/m^3 until 1680 kg/m^3. High bulk density is an indicator of low soil porosity and soil compaction.

2.4.6 PARTICLE SIZE DISTRIBUTION

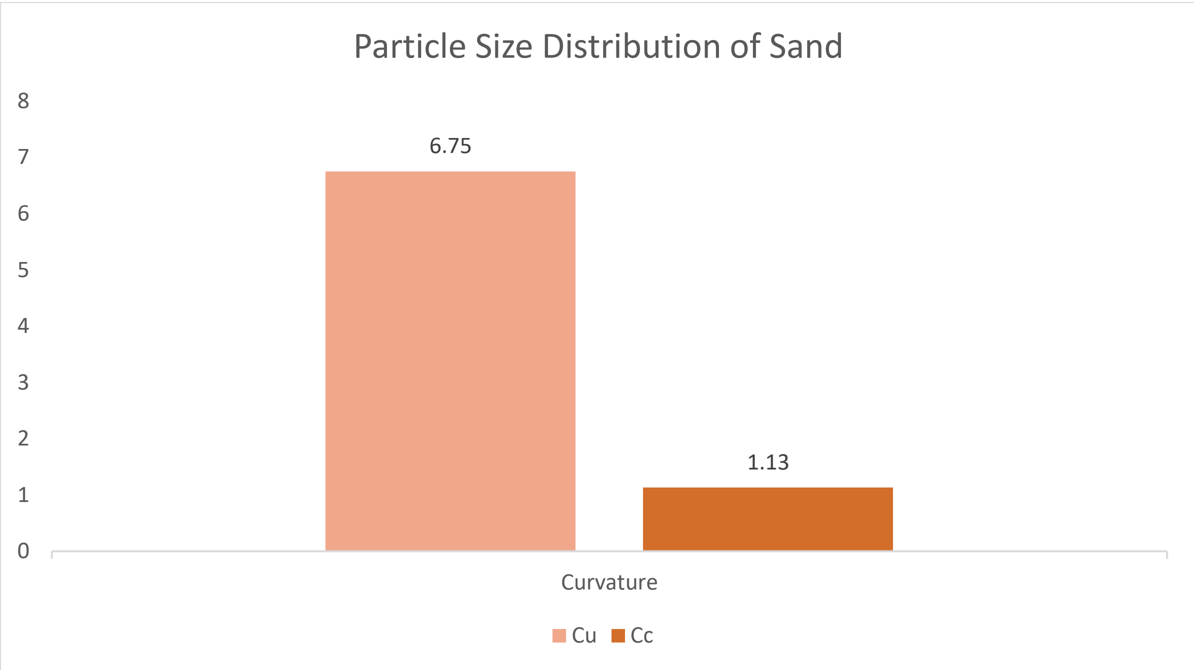

Figure 2.11: Graph Particle Size Distribution of Sand

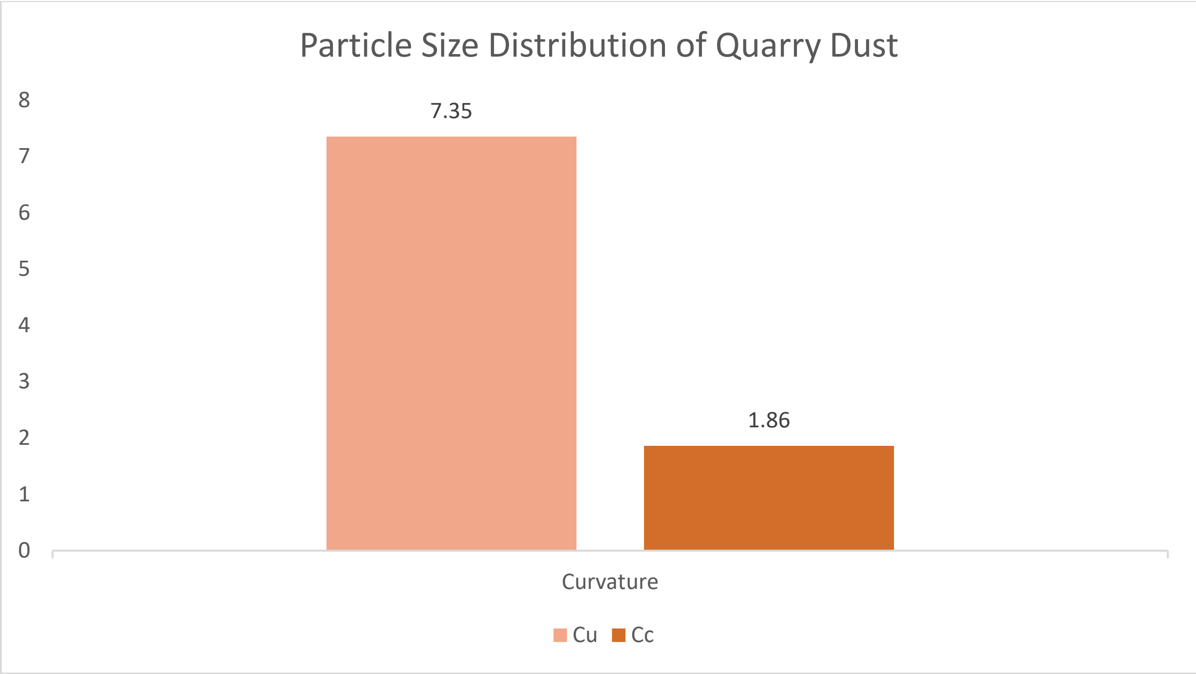

Figure 2.12: Graph Particle Size Distribution of Quarry Dust

According to Elseknidy et al. (2020), the sieve analysis test was carried out to evaluate the particle size distribution of river sand and quarry dust as per ASTM: C 136-06. Both the coefficient of uniformity (Cu) and the coefficient of curvature (Cc) have been calculated to check whether the fine aggregates are well or poorly graded as defined in ASTM-D2487. The particle size distribution between quarry dust and river sand is shown in Table 2.5 above.

The grading classification of fine aggregates depends on the coefficient of uniformity (Cu) and the coefficient of curvature (Cc) values. For aggregates to be well graded, the value of (Cu) must be greater than 6, while the value of (Cc) must be between 1 and 3. Otherwise, the fine aggregates will be poorly graded, as defined in ASTM-D2487.

The well-graded aggregate contains minimum voids; therefore, a minimum quantity of paste is needed to fill them. The distribution of particle size of river sand and quarry dust resulting from the sieve analysis test is shown in Table 2.5. As shown in Table 2.5, the river sand and quarry dust have a coefficient of uniformity (Cu) of 7.35 and 6.75, with a coefficient of curvature (Cc) of 1.86 and 1.13, respectively. As a result, both river sand and quarry dust are well graded.

2.5 INDUSTRIAL REVOLUTION 4.0 (IR 4.0)

The fourth industrial revolution, or IR 4.0, is an unprecedented technological change in human history. It will soon evolve into combinations of digitalization technologies in disciplines like engineering, physics, and biology, opening up whole new possibilities. Through IR 4.0, a setting will be established in which the global processes of the production chain take place both physically and digitally, fusing together into a flexible and seamless system. In addition to processes and objects that are intelligent and connected, IR 4.0 also refers to a far wider mentality that has a significant impact on the global structures of politics, society, and economics. IR 4.0 is expected to have significant benefits and a significant impact on global economies, and it is also having an impact on the development of a number of advances in numerous disciplines, such as quantum computing, gene sequencing, renewable energy, and nanotechnology (Schwab, 2016).

After IR 4.0's conceptualization was made public in 2011, the idea expanded and progressed to the point where some of the theories have actually been put into practise. Everyone has been impacted by the new industrial revolution in some way, albeit everyone has been influenced in various ways. As people become used to the reality of IR 4.0, national and worldwide trends are happening. While breakthroughs have been made, mounting evidence suggests that there are strong and obvious links between the development of technology, governmental policy, and the market (Yang & Gu, 2021).

Academics, entrepreneurs, policymakers, and members of the public are constantly debating the problems associated with the now-global Industry 4.0. For instance, economists are increasingly focusing on the effects that the idea of Industry 4.0 is having on national and international economic systems, particular industrial domains, the labour force, and capital markets. Due to advances in technology and creative production methods, the global industrial context has undergone a substantial transition in recent years. Despite the concept of Industry 4.0's growth, academics have barely touched on this topic. As a result, neither a broad definition nor a level of agreement on the subject have been reached (Pereira & Romero, 2017).

The landscapes of many firms are changing quickly, and these changes affect the entire value chain. The costs of transactions and deliveries are significantly decreased as a result of this, which also includes research and development (R&D), production, transportation, and customer services, among others. Manufacturing is projected to be significantly impacted by IR 4.0, which will change production processes significantly and drive the convergence of real-world and digitised elements thus creating the Internet of Things (IoT), or a universal internet (Rayhan & Ahmad, 2021). According to Erboz (2017), below are the application of the Fourth Industrial Revolution operates through:

I. Mobile devices
II. Internet of things (IoT) platforms
III. Location detection technologies (electronic identification)
IV. Advanced human-machine interfaces
V. Authentication and fraud detection
VI. Smart sensors
VII. Big analytics and advanced processes
VIII. Multilevel customer interaction and customer profiling
IX. Augmented reality/wearables
X. On-demand availability of computer system resources
XI. Data visualisation and triggered "live" training

2.6 INTERNET OF THINGS (IOT)

The Internet of Things (IoT) is a new paradigm that makes it possible for electrical gadgets and sensors to communicate with one another over the internet to improve lives. Smart devices and the internet are used by IoT to offer creative solutions to a range of problems and difficulties affecting various economic, governmental, and public/private sectors worldwide (Sfar et al., 2017). IoT is steadily becoming into a significant component of life that is perceptible everywhere in the world. IoT, as a whole, is a technological advancement that combines a wide range of smart systems, frameworks, intelligent devices, and sensors.

Moreover, it takes advantage of quantum and nanotechnology in terms of storage, sensing and processing speed which were not conceivable beforehand (Gatsis & Pappas, 2017). To demonstrate the potential effectiveness and applicability of IoT changes, extensive research studies have been conducted and are available in the form of scholarly articles, press reports, both on the internet and in the form of printed materials. It could be used as a pre-work before creating original, inventive company concepts while taking security, assurance, and interoperability into consideration.

The fact that some prospective IoT application areas are currently unexplored or lack sufficient guidance on how to approach them is a clear indicator that more intensive research effort should be done in this difficult area in order to produce fresh and significant potential advantages for society. IoT technologies should therefore play a significant role in the future because their relevance and importance are more than evident. The general present market structure of IoT technologies is presented in Figure 1 below where it is evident that the majority of the market is focused on Smart Cities and Industrial IoT (Nižetić et al., 2020). If recent projects in IoT technologies are being analysed, then most of them are in the field of smart cities and industrial IoT. Other significant potentials are connected buildings, connected cars and energy segments, but lower than the first two mentioned fields.

According to Guilhot et al. (2021), Internet of Things (IoT) monitoring systems are frequently utilised for geotechnical data, either alone or in conjunction with unique technological aspects. The implementation of wireless networks of commercially accessible sensors to collect, transmit, and interpret land displacement data is gradually replacing traditional manual reading. These surveillance networks provide a number of advantages:

I. Do not require human interaction to collect the data
II. Require minimum maintenance
III. Battery powered
IV. Low power consumption
V. Connectivity to the internet facilitates real-time data visualization and further analyses

Despite these benefits, motion sensors only give discrete information confined to the sensor's footprint and a specified time range, resulting in potential information gaps. A significant amount of work in the field of monitoring has recently been concentrated on displacement modelling and forecasting in order to improve monitoring systems while lowering their costs. These predictive systems frequently use the structure's initial geotechnical model, and data acquired by IoT devices is used to update the model and calculate the structure's safety factor as an example. Thus, Finite Element Method (FEM) such as Plaxis 2D and Plaxis 3D are designed for two- and three-dimensional displacement and stability assessments in geotechnical engineering and rock mechanics.

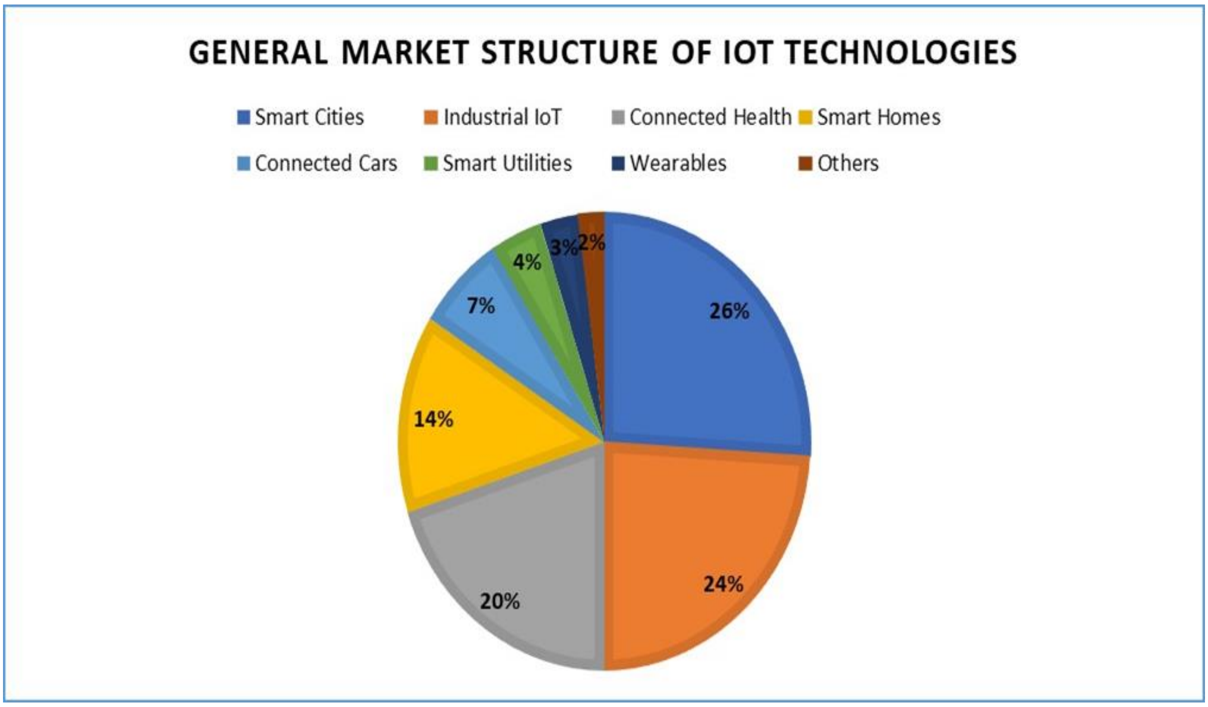

Figure 2.13: Pie Chart of General Market Structure

2.7 FINITE ELEMENT METHOD (FEM)

Finite element method is very popular in the field of geotechnical engineering. It is also popular method for numerically solving differential equations that appear in mathematical and engineering modelling. Engineers and scientists utilise the method frequently so that they can mathematically model and numerically solve exceedingly complicated problems. Engineering analyses are carried out to evaluate designs whereas scientific analyses are carried out to gain insight into and ideally forecast natural events.

The ability to foresee how a design will operate and how a natural phenomenon will occur is extremely valuable. Designs may be made safer and more cost effective, and understanding into and forecast of nature can aid in catastrophe prevention. To solve a problem, the finite element method breaks a big system into smaller, simpler components known as finite elements. The finite element method then approximates a solution by using the calculus of variations to minimise an associated error function.

The main advantages of the finite element method are its suitability and flexibility for analysing various boundary conditions and different materials properties. As a result, using the finite element method tremendously enriches many lives. Moreover, the application of this method is definitely not new.

For over forty years, it has been used in numerous engineering practises. From the 1970s through the mid-1990s, the approach could only be used by large colleges that could afford to have so-called main frame computers. As time passing by and computer processors rapidly involving, many commercial geotechnical finite element methods are becoming available including Phase 2, Geo5fem, Gfas, Midas, Plaxis 2D and many more geotechnical related (Liong, 2014).

2.8 PLAXIS 2D

Plaxis 2D is powerful and user-friendly finite element package intended for 2D analysis of deformation and stability in geotechnical engineering and rock mechanics. Plaxis 2D provide the ability to model diverse geotechnical problem from single integrated application. The user can also analyse the deformations and the stability of project ranging from excavation embankment and foundation to seismic events tunnelling mining geomechanics and rock mechanics. Plaxis 2D uses the Fine Element Method (FEM) to solve the unbalanced caused by geotechnical work like raising dams and embankments, clothing, removal of soils for excavation returns

This numerical simulation method also was used to assess the effects of modelling factors on soil strength estimates, as well as to compare, correlate, and verify laboratory testing and computer modelling (Lankaran et al., 2022). Such changes will cause an out of balance that is then solved via stress-strained relationship using so-called constitutive soil models to replicate the deformation behaviour of a real soil while also taking the soil strength into account. The Plaxis 2D software also comprises three sub programs namely the input program, the calculation program and the output program shown in figure 2.14 below. It performs analysis with either an assumption of plane strain or axi-symmetry with 6-noded or 15-noded triangular elements.

Figure 2.14: Plaxis 2D Logo

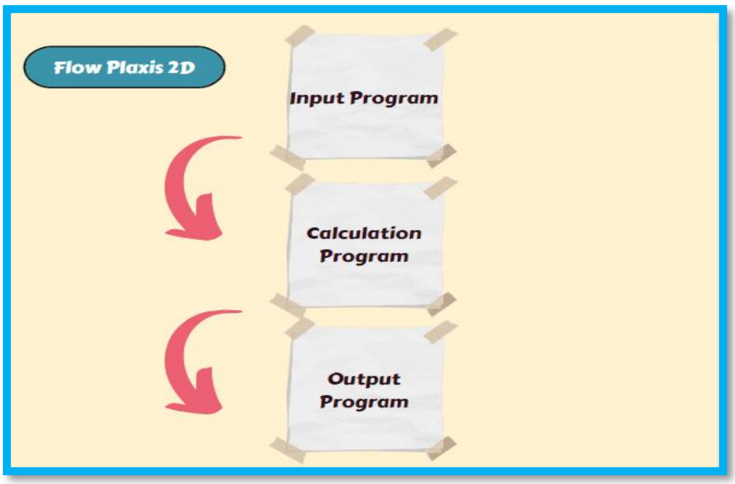

Figure 2.15: Flow of Plaxis 2D

2.9 CONCLUSION

Implementing technology will benefit the construction sector by improving efficiency and reducing waiting lists. Furthermore, it can be accessible from anywhere and simplifies daily work by utilizing technology like apps or systems. Project managers, site engineers, and site supervisors can benefits many geotechnical precaution as software such as Plaxis 2D can give them proper evaluation and simulation of every situastion possible in geotechnical department. By understanding the scope of work and the uses of every material in ground treatment especially involving remove and replace, thus the process of creating model will be a lot easier as the understanding towards the work scope enable user to implement materials properties with ease.

As people often depicting quarry dust as tiny dust material is actually inccorect and that is why it is important to conduct literature analysis and study past papers in similar line of work to realize how close quarry dust is in properties with sand. Geotechnical properties were conduct to prove quarry dust can indeed serve as alternatives even as partial substitute. Then it is important to learn about Industrial Revolution (I.R 4.0) and how it influenced Internet of Things (IoT) applications in creating Geotechnical Engineering Software such Midas, GFas, Plaxis 2D and many more.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This research will define the strategy and describe how the process of this analysis was conducted. Furthermore, from the start to the end of the project, this chapter will explain the process and examine the measures taken to identify the problem. This method will be utilised to achieve the objectives of this project and assure a faultless outcome. When the task is completed, the analysis will examine it to determine how effective the proposed materials are. By recognizing industry-based problems through industrial problem-based solving in the studied region, solutions can be taken. This chapter will also describe all the Input and Output materials of Plaxis 2D and its functions. By understanding general uses of the tool, this part will also discuss geometry model selected both in sketching and Plaxis 2D while also verify each parameter selected for Input materials. Overall, this chapter will thoroughly describe each step required in carrying out this investigation. With planning that has been done well and neatly, the analysis of subgrade in replacing sand with quarry dust can be modelled and analysed well without problems.

3.2 ANALYSIS PROCESS

This approach is crucial for modelling and to achieve expected results after calculation. It is important to track the steps taken from implementation to the identification of implementation-related problems. Improvements must be done if a critical issue is a substantial reason why the task was not successfully completed. Finally, control measures must be implemented in order to keep the flow stable.

3.3 ANALYSIS FRAMEWORK

The method is split into several phases in this analysis and will be discussed in detail. In addition, there are model for this analysis that had to be created and references data as well from literature review regarding parameters of material that will be applied to Plaxis 2D.

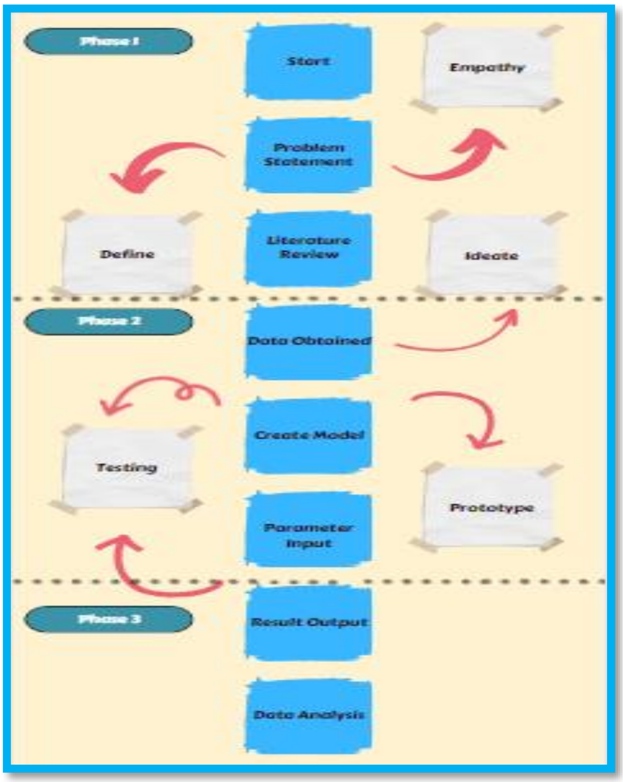

Figure 3.1: Analysis Framework

3.4 PROBLEMS DISCOVERY

High demand and rapid rise in price of sand has resulted in extensive exploitation of river sand. With economic rises in demand of sand as important raw material in various civil construction as with the prices, the urge to find alternatives to this material is important. Hence why quarry dust might be the material able to produce the same outcome involving subgrade settlement in this analysis. Next, design of subgrade settlement in Remove and Replace Method resulted in heavy usage of sand. As the amount of sand needed for each chainage varies, still the amount uses of sand for each chainage are still massive considering the length of excavated area can go up to 1km per chainage. Thus, the material needs to cover the whole area with applied thickness of 0.45m. Lastly, the lack of implementation regarding analysis software among work department in geotechnical industry. Considering technological changes occur every year passing by, IoT has become significant component of life that is perceptible everywhere in the world. By implementing Plaxis 2D to help engineers construct solution to any given geotechnical issues in modern days is very necessary.

3.5 DATA COLLECTION

The main purpose of this step is by conducting analysis for each property of materials used to get accurate outcome from the analysis of model. One significance method involving collecting data which is Primary Data. Primary data is obtained from the internet, from journal, research papers, book, and comprehensive literature review. Primary data is data received directly from the data source without using any existing databases. It is frequently obtained exclusively for a study endeavour and might be widely distributed for use in other research projects. Primary data is always accurate, credible, and objective because it was acquired for the aim of solving a specific research topic. Such example of data collection has been shown in Chapter 2 involving Literature Review of this analysis. Thus, it is important to identify the issue because it enables the finding of various solutions to a problem after it has been identified. No real efforts can be made to solve a problem unless it has first been identified.

3.6 GENERAL PURPOSE IN PLAXIS 2D

PLAXIS 2D is a tool for 2D finite element geotechnical analysis. In addition to plastic deformation analysis and other analysis choices, it can do slope stability analysis. It is mainly divided into three sections as shown in Table 1 below.

Table 3.1: Plaxis 2D General Phase

Phase	Details
First Phase: Pre-Process	Plaxis 2D Input: I. Model creation II. Actual physical representation of the problem III. Initial situation of building process IV. Simulate different construction process

Second Phase: Calculation 	Calculation Phase: I. Calculation continued from pre-process of Plaxis 2D Input II. The results will be shown in Plaxis 2D Output
Third Phase: Post-Process 	Plaxis 2D Output: I. View and inspect results II. Different views such as the entire model at a specific moment during construction III. Follow specific point during the whole construction process

3.7 PLAXIS 2D INPUT (PRE-PROCESS)

There are five steps available that must be done in Plaxis 2D Input. Five working modes that are categorized into two colour which are Blue Mode and Green Mode:

I. Soil Mode

In this mode where soil layer and its respective profile and stratigraphy is defined in the soil mode using the Borehole feature of the program.

Figure 3.2: Logo in the Interface

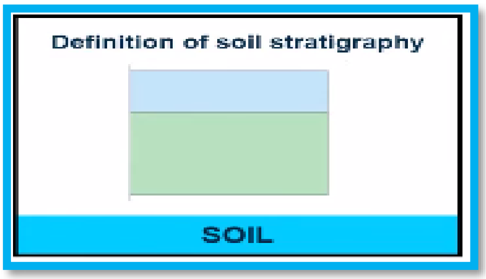

Figure 3.3: Soil Mode

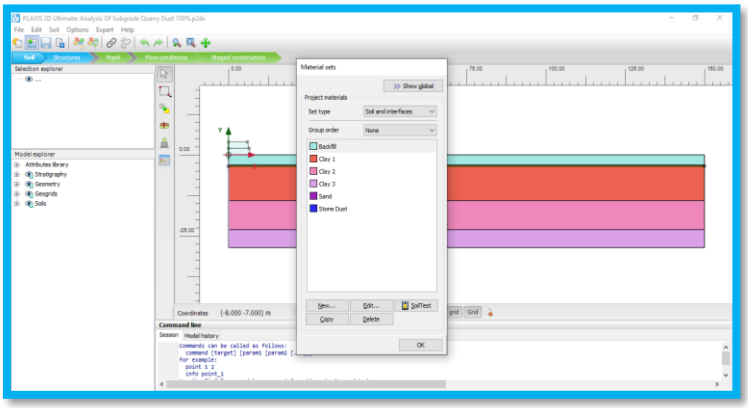

Figure 3.4: Soil Mode Interface

II. Structures Mode

In this mode where structural elements, loading conditions and boundary conditions is defined. The geometry of a model is also defined after completing two modes.

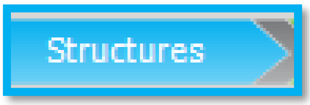

Figure 3.5: Logo in the Interface

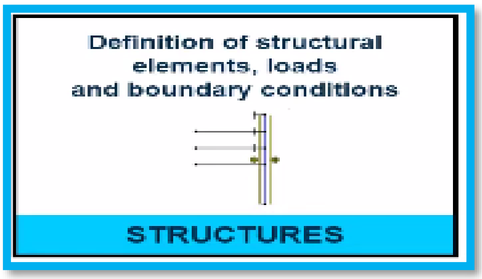

Figure 3.6: Structures Mode

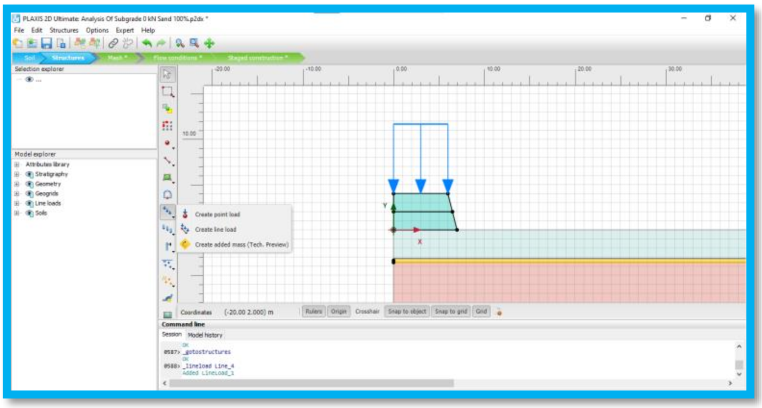

Figure 3.7: Structures Mode Interface

III. Mesh Mode

In this mode where Finite Element (FE) mesh is created and generated.

Figure 3.8: Logo in the Interface

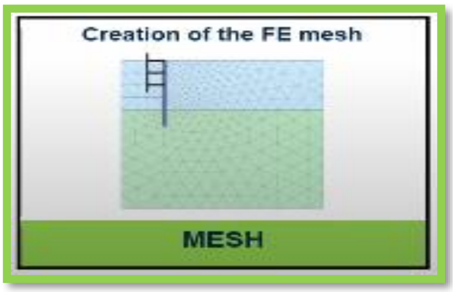

Figure 3.9: Mesh Mode

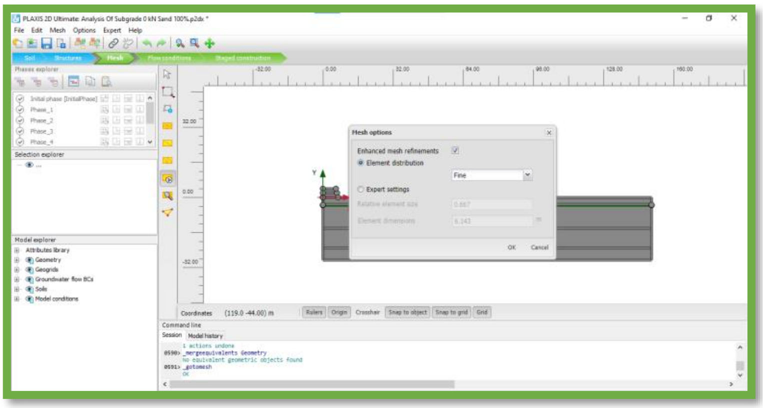

Figure 3.10: Mesh Mode Interface

IV. Flow Conditions Mode

In this mode where configuration needed for groundwater conditions and flow conditions is set up.

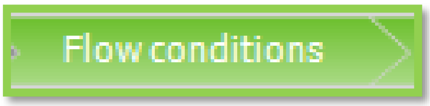

Figure 3.11: Logo in the Interface

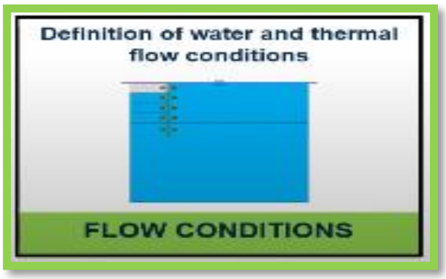

Figure 3.12: Flow Conditions Mode

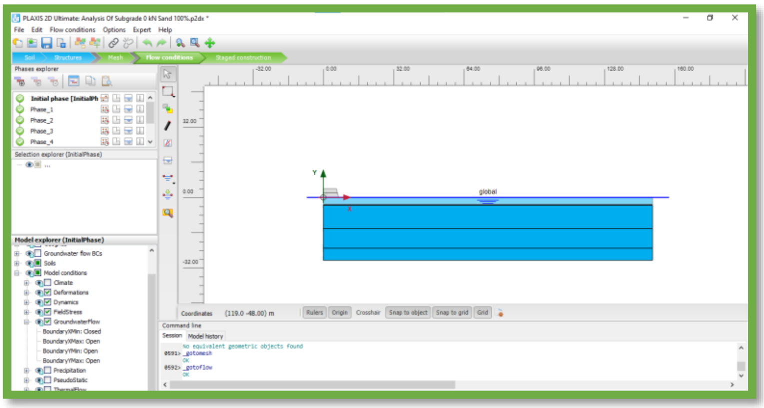

Figure 3.13: Flow Conditions Mode Interface

V. Staged Construction Mode

In this mode where different calculation phases are set up where simulation of construction in different stages can be done.

Figure 3.14: Logo in the Interface

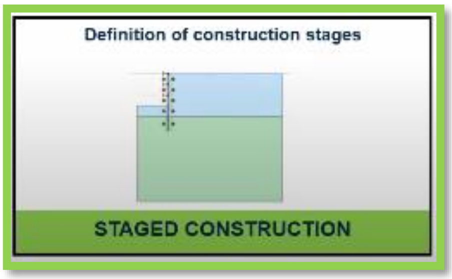

Figure 3.15: Staged Construction Mode

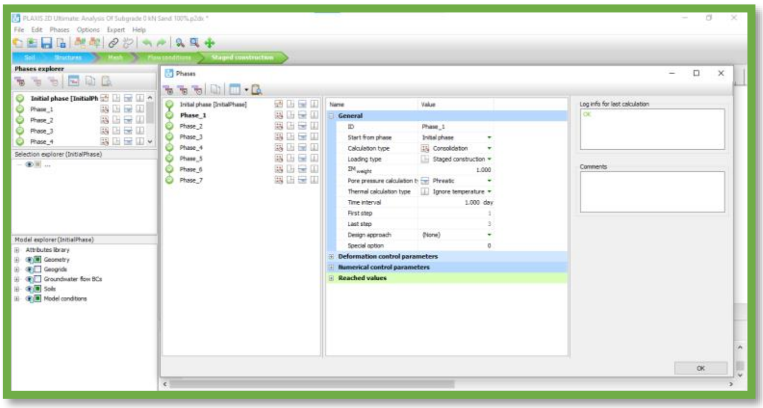

Figure 3.16: Staged Construction Mode Interface

3.8 PLAXIS 2D OUTPUT (POST-PROCESS)

Once all the mode for pre-process is done, then the calculation can be proceeded. When all calculations are completed, then only the result can be inspected. One of the outcomes that can be see are deformation profile, settlement profile, excess pore pressure and many more. Thus, in post-process, all the result can be inspected, and behaviour of the model can be observed.

Figure 3.17: Example of calculation after pre-process

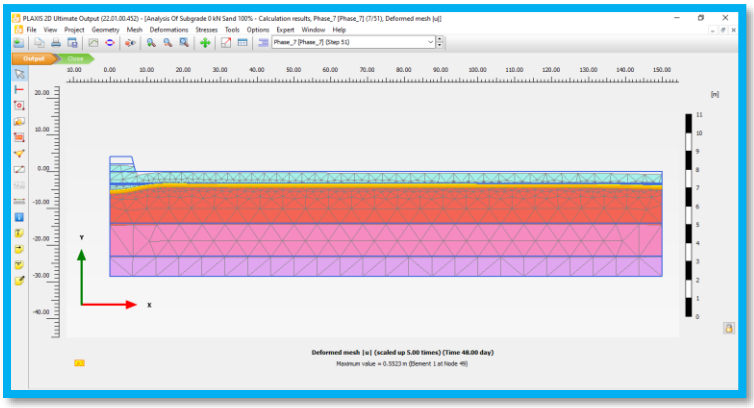

Figure 3.18: Example of Result in Plaxis 2D Output

3.9 GEOMETRY MODEL

A specific Chainage located involving Section 3 in Setiu, Terengganu has been chosen as future references for cross section model that will be integrated in Plaxis 2D. The chainage chosen from this Ground Treatment is from Chainage 105 + 730 until Chainage 106 + 030 which cover a distance of 300m. This particular Chainage was chosen to do Ground Treatment involving Remove and Replace Method which one of the main reason the model was based off after this. Max treatment depth that was instructed when excavate Unsuitable Soil Material (USM) is 3.6m according to given drawing. The excavation of soft soil will usually stop until the exact first layer of clayey soil after 3.6m of excavation according to given drawing.

With 4m of embankment presented in the figure below, the focus will be on the settlement with layers of geotextile and particularly sand, which is subjected to change later on in this analysis. The raw material percentage will be divided into five different models which capitalized different ratio of sand and quarry dust for each model. First, there is a need to prepare the sketching of the model first before implementing it into Plaxis 2D. There will be four types of sketches that will be shown in figure below. First involving two different load that will be simulate alongside the other with three different coordinate involving Point X, Point Y and Point Z. The section taken based on the model is only symmetrical as the simulation that occur in this half will happen exactly to the other half. Thus, this can be considered as the right-side section of this model. The sketch models were prepared with different colour to differentiate type of soil used which will be important parameter in Plaxis 2D later.

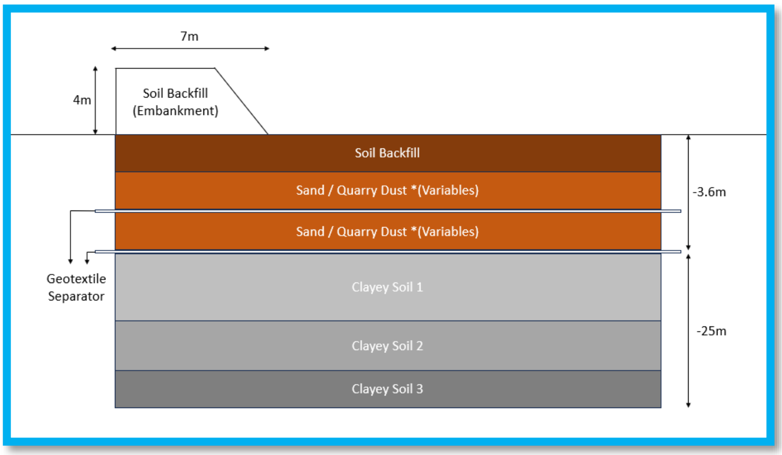

Figure 3.19: Geometry Model (No Load)

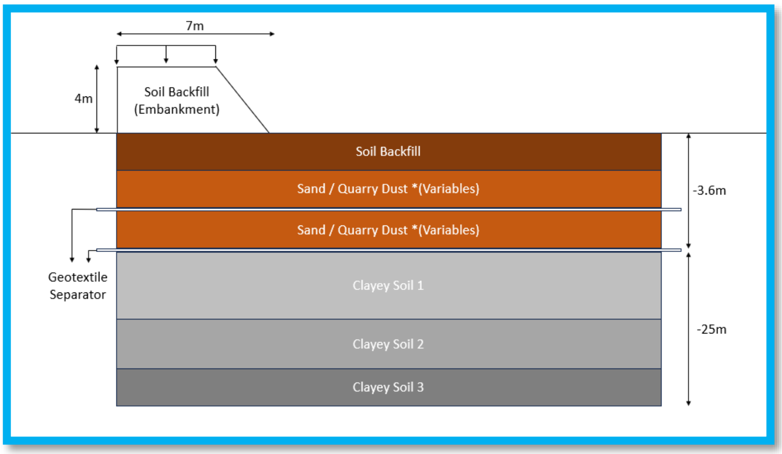

Figure 3.20: Geometry Model (Line Load: 10kN)

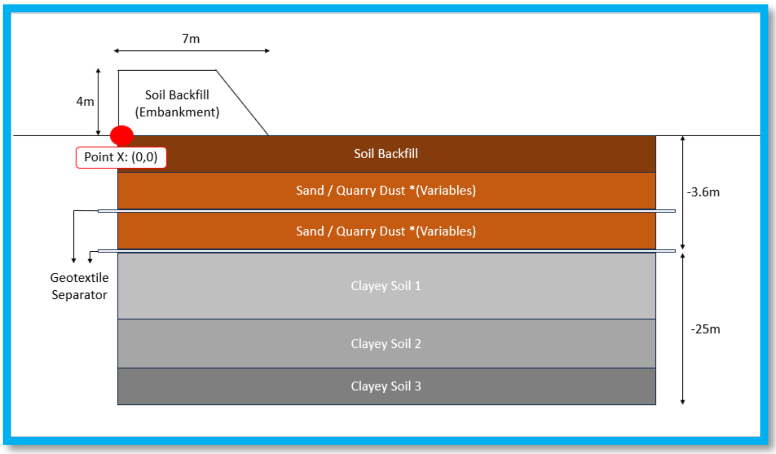

Figure 3.21: Geometry Model (Point X: 0,0)

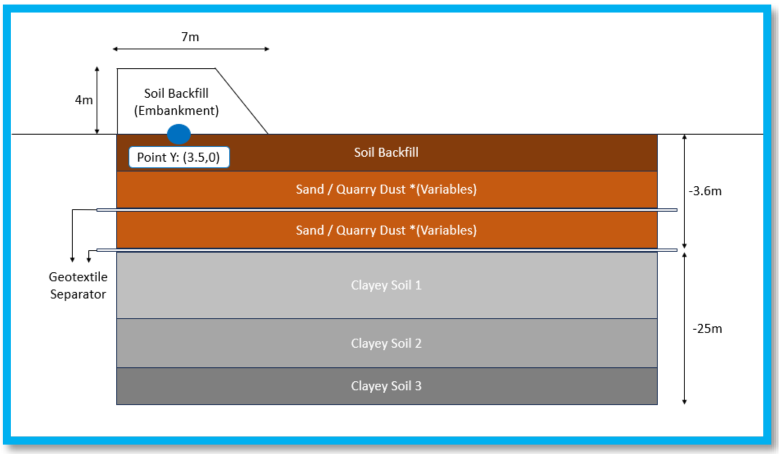

Figure 3.22: Geometry Model (Point Y: 3.5,0)

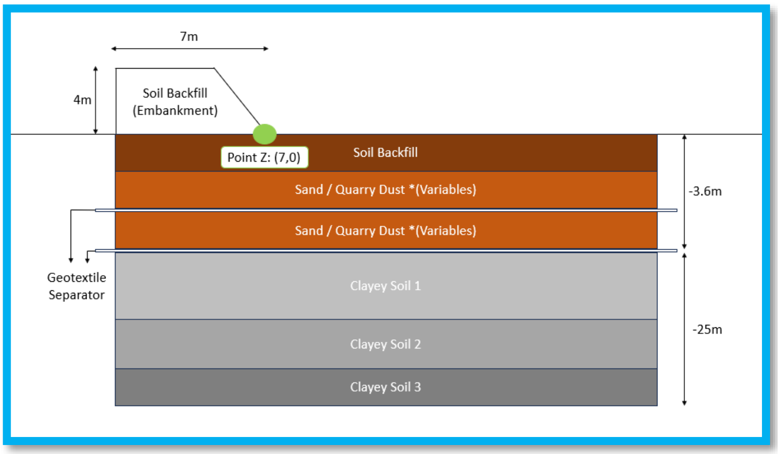

Figure 3.23: Geometry Model (Point Z: 7,0)

With the preparation of given sketches, the model will be implanted in Plaxis 2D with the same width and height for each layer of soil. Three layers of clayey soil created using soil polygon with total of 25m in height as stated in the drawing. The placement of geotextile separators was put above clayey soil using geogrid structure with sand blanket following up after. The two processes were repeated for another layer. Soil backfills layer will fill up the rest as 3.15m is filled. Thus, completing 27m of subgrade layer involving model proposed. For embankment, is by designing according to the height and width which is 4m and 7m respectively. Placement of line load was put is 10kN which to act as comparison when analysing data between non load and load placement to the settlement. For coordinates, three points were selected as observation to deformations which are Points X (0,0), Points Y (3.5,0) and Point Z (7,0). Figures below show the model implemented in Plaxis 2D after sketches.

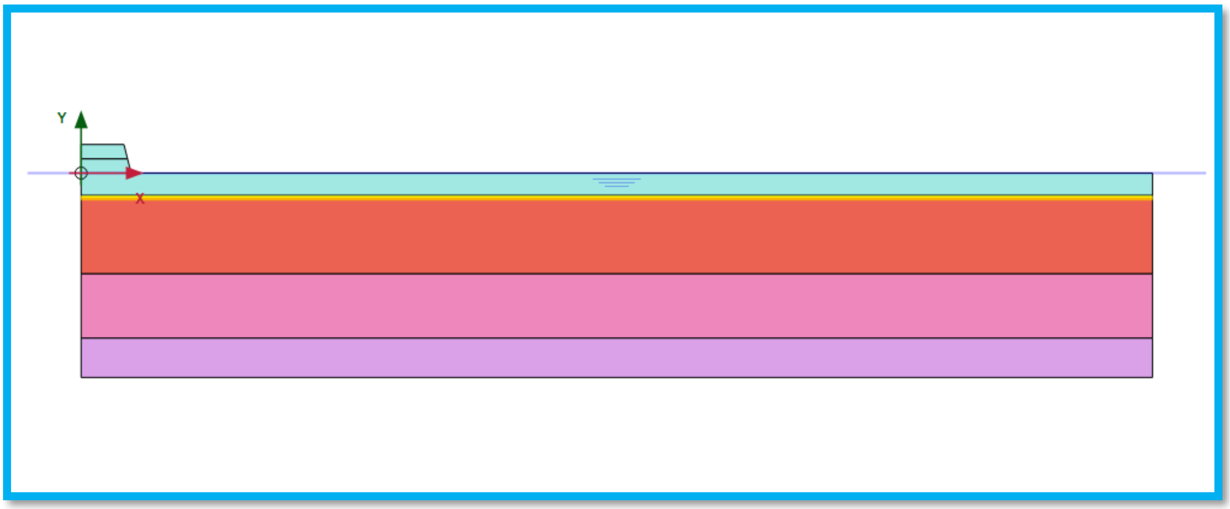

Figure 3.24: Completed Model in Plaxis 2D (No Load)

Figure 3.25: Completed Model in Plaxis 2D (Line Load)

3.10 MATERIAL PROPERTIES

After designing the model needed, materials sets were created consisting of two types of project materials. First is soil and interfaces where seven materials were created which are soil backfills, quarry dust, sand and three different layers of clayey soil. Second is geogrid where two materials were created involving geotextile layer. Each materials have different properties need to be fill. As such through different article and past research, table 3.2, table 3.3 and table 3.4 below summarizes soil properties used in the Plaxis 2D modelling.

Table 3.2: Soil Parameter 1

Parameter	Clayey Soil 1	Clayey Soil 2	Clayey Soil 3
Dry Unit Weight, y_{unsat} (kN/m³)	15.0	15.5	15.0
Bulk Unit Weight, y_{sat} (kN/m³)	17.5	17.5	18.0
Modified Compression Index, λ*	0.09	0.055	0.04
Modified Swelling Index, k*	0.037	0.025	0.015
Modified Creep Index, μ*	2.14×10^{-4}	2.40×10^{-4}	1.00×10^{-3}
Young Modulus, Eref (kN/m²)	-	-	-
Dilatancy Angle, Ψ (°)	0	0	0
Friction Angle, Φ (°)	20	18	30
Cohesion, C (kN/m²)	5	2	15
Poisson Ratio, υ	-	-	-
Void Ratio, e_{init}	0.5	0.5	0.5
Groundwater Type	USDA	USDA	USDA
Groundwater Method	Van Genuchten	Van Genuchten	Van Genuchten
Soil Class	Clay	Clay	Silty Clay
< 2μm, (%)	70	70	48
2μm − 50μm (%)	13	13	45
50μm − 2mm (%)	17	17	7
Horizontal Permeability, k_x (m/day)	4×10^{-4}	4×10^{-3}	5.5×10^{-2}
Vertical Permeability, k_y (m/day)	2×10^{-4}	2×10^{-3}	2.7×10^{-2}

Table 3.3: Soil Parameter 2

Parameter	Soil Backfill	Sand	Quarry Dust
Dry Unit Weight, y_{unsat} (kN/m³)	18.0	18.0	18.0
Bulk Unit Weight, y_{sat} (kN/m³)	18.0	20.0	23.87
Modified Compression Index, λ*	-	-	-
Modified Swelling Index, k*	-	-	-
Modified Creep Index, μ*	-	-	-
Young Modulus, Eref (kN/m²)	50 000	30 000	25 000
Dilatancy Angle, Ψ (°)	3	3	3
Friction Angle, Φ (°)	33	33	31.12
Cohesion, C (kN/m²)	1	1	6.430
Poisson Ratio, υ	0	0.3	0.35
Void Ratio, e_{init}	0.5	0.5	0.5
Groundwater Type	Standard	Standard	Standard
Groundwater Method	-	-	-
Soil Class	Course	Course	Course
< 2μm, (%)	10	10	13
2μm − 50μm (%)	13	13	13
50μm − 2mm (%)	77	77	77
Horizontal Permeability, k_x (m/day)	0	0.5	0.5
Vertical Permeability, k_y (m/day)	0	0.5	0.5

Table 3.4: Geotextile Parameter

Parameter	Geotextile 1	Geotextile 2
Material Type	Elastic	Elastic
Properties	Isotropic	Isotropic
Axial Stiffness 1 (kN/m)	1000	2500
Axial Stiffness 2 (kN/m)	1000	2500

There are two kind of materials model that is used with different properties as shown in tables above. Mohr-Coulomb (MC) and Soft Soil Creep (SSC) are two model that has been implemented on each material. Mohr-Coulomb model has been used for materials such as soil backfill layer including embankment fill, sand layer and also quarry dust layer. As known before, Mohr-Coulomb model is well-known model used as a first approximation of soil behaviour. This model usually been used for simple analysis of subgrade and embankment materials. By also considering the type of materials used, drained materials for drainage type were selected for this model. Meanwhile for Soft Soil Creep model, which considered creep condition had been used to model the foundation involving three different layers of clayey soil. Due to the base of the earth materials is clay with low shear strength and permeability, Soft Soil Creep is suitable to be used in this model.

This model is also often used to simulate the time dependent behaviour of soft soils like normally consolidated clays. The model can predict more realistic undrained shear strength compared to the Mohr Coulomb model. Because of less permeability involving clay as material, this model was selected as undrained materials for drainage type. Furthermore, a layer of geotextile has been used as reinforcement alongside sand and quarry dust which is necessary in remove and replace method. the only difference between both reinforcement materials is in axial stiffness. For lower geotextile, the amount of stiffness is 1000 kN/m, while for upper geotextile the amount of stiffness is 2500 kN/m. Both separators were put under the layer of variables measured for this model.

By completing the properties for each material through literature review and past of research of the same project thus important parameters such as dry unit weight, bulk unit weight, young modulus, cohesion, friction angle and dilatancy angle can provided as listed in tables above. These properties will be fill in Plaxis 2D Input as shown in figure below. Properties of sand was selected as example of properties interface in Plaxis 2D.

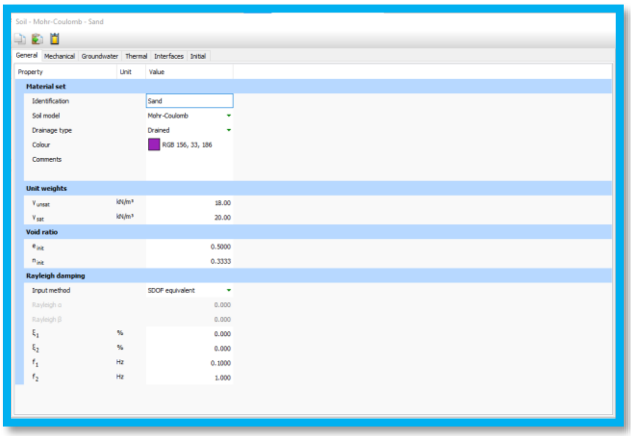

Figure 3.26: General Properties of Sand in Plaxis 2D

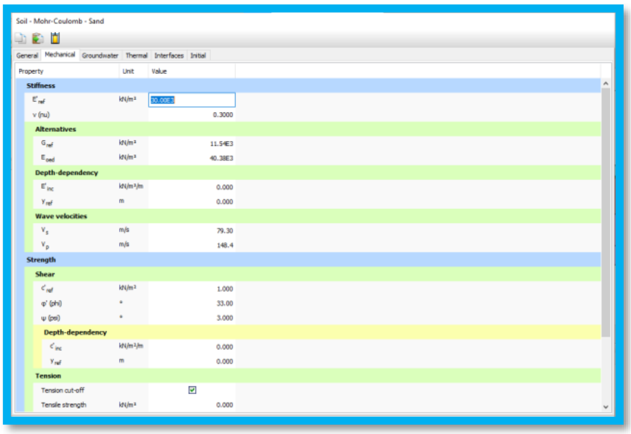

Figure 3.27: Mechanical Properties of Sand in Plaxis 2D

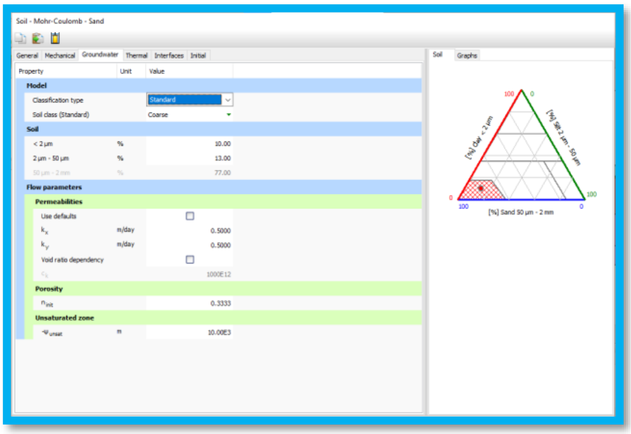

Figure 3.28: Groundwater Properties of Sand in Plaxis 2D

3.11 CONSTRUCTION ANALYSIS

By entering all of the given parameters from tables above, the model is now complete alongside each material properties. Thus, the requirement from Soil Mode and Structure Mode in Plaxis 2D Input is now finished. By proceed to Mesh Mode, where Finish Element (FE) mesh is created. This has been done automatically by software. All of the models were then generated using fine mesh options to which allow increasing in accuracy of each model when analyses. Moreover, the model was analysed using a two-dimensional plain strain model using 15-node elements for both foundation soil and fill embankments.

After meshing the geometry is Flow Conditions Mode where configuration needed for groundwater conditions and flow conditions is set up. The subtree of model condition in this mode is groundwater flow where Boundary of X Minimum is close to restricts flow of water as the model is symmetric. Meanwhile the other boundary is open to allow the flow of water on selected area. Last mode in Plaxis 2D Input is Staged Construction Mode where different calculation phases are set up where simulation of construction in different stages can be done. Seven phases were created for non-load model while eight phases were created as the presence of loading is permitted.

Once the geometry model has been created and the finite element mesh has been generated, the initial stress state and the initial configuration must be specified. This is done in the initial conditions part of the input program in Plaxis 2D. The finite element in Plaxis 2D offers six calculations in each construction phases which are plastic calculation, consolidation calculation, safety calculation, dynamic calculation, fully coupled flow deformation calculation and dynamic with consolidation calculation. For all phase of calculation, consolidation calculation was chosen for this analysis.

According to Zewdu (2020), consolidation analysis should be selected when it is necessary to analyse the development or dissipation of excess pore pressures in water-saturated clay-type soils as a function of time. Plaxis 2D allows for true elastic plastic consolidation analyses. In general, a consolidation analysis without additional loading is performed after an un-drained plastic calculation. It is also possible to apply loads during a consolidation analysis. The staged construction of the model was shown in table 3.5 below for each phase.

Table 3.5: Staged Construction Parameter

Staged Construction	Calculation Type	Loading Type	Duration (Day)
Clayey Soil 1, Clayey Soil 2, Clayey Soil 3	KO Procedure	Staged Construction	0
Clayey Soil 1, Clayey Soil 2, Clayey Soil 3, Geotextile Separator 1	Consolidation	Staged Construction	1
Clayey Soil 1, Clayey Soil 2, Clayey Soil 3, Geotextile Separator 1, Sand 1	Consolidation	Staged Construction	2
Clayey Soil 1, Clayey Soil 2, Clayey Soil 3, Geotextile Separator 1, Sand 1, Geotextile Separator 2	Consolidation	Staged Construction	1
Clayey Soil 1, Clayey Soil 2, Clayey Soil 3, Geotextile Separator 1, Sand 1, Geotextile Separator 2, Sand 2	Consolidation	Staged Construction	2
Clayey Soil 1, Clayey Soil 2, Clayey Soil 3, Geotextile Separator 1, Sand 1, Geotextile Separator 2, Sand 2, Soil Backfill	Consolidation	Staged Construction	14
Clayey Soil 1, Clayey Soil 2, Clayey Soil 3, Geotextile Separator 1, Sand 1, Geotextile Separator 2, Sand 2, Soil Backfill, Embankment Fill 1	Consolidation	Staged Construction	14
Clayey Soil 1, Clayey Soil 2, Clayey Soil 3, Geotextile Separator 1, Sand 1, Geotextile Separator 2, Sand 2, Soil Backfill, Embankment Fill 1, Embankment Fill 2	Consolidation	Staged Construction	14

Table 3.5 above shows staged construction of seven phase of the model created in Plaxis 2D. With no load total duration of given replace and refill method is 48 days. With applied load, additional phase has been created to make eight phases in total which the total duration of given replace and refill method is 50 days. This model uses 100% of sand as raw material which act as variables for other model with quarry dust will also be mixed alongside this raw material with different ratios. The interface of staged construction for this model in Plaxis 2D is shown below. After setting up staged all parameter in staged construction mode, then the model can finally be simulated as the results will be shown in Plaxis 2D Output.

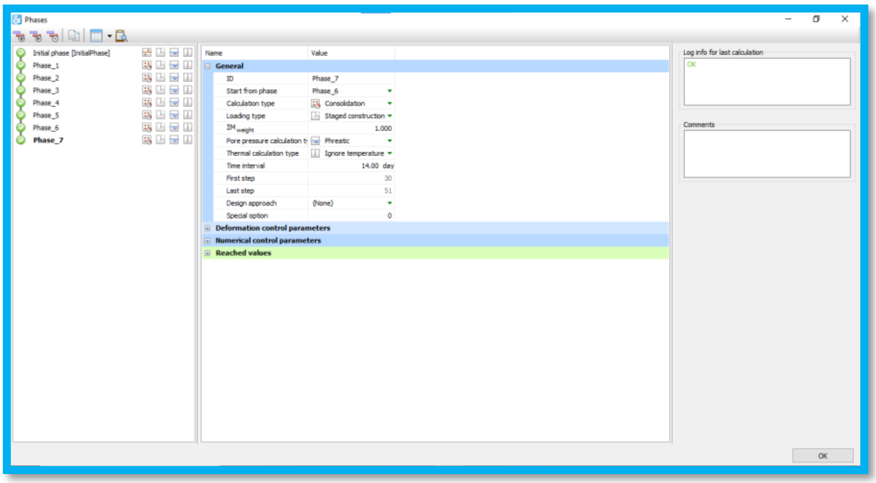

Figure 3.29: All Seven Phases in Staged Construction

3.12 CONCLUSION

In conclusion, methodology is a critical aspect of research that outlines the procedures, tools, and techniques used to collect and analyse data. It serves as a blueprint for conducting research, ensuring that the data collected is reliable, valid, and relevant to the research question or problem. The choice of methodology depends on the research design, the type of data collected, and the research question being investigated. From finding problems, define the problems through various research, create an idea to overcome problem, implement a model to help solve problem and lastly examine model to help gain data for result analysis. Overall, the methodology of research is an essential component that should be carefully considered and planned to ensure the research is conducted in a rigorous, ethical, and meaningful way. It helps researchers to answer research questions, test hypotheses, and generate new knowledge that can be applied in various fields of study.

CHAPTER 4

DATA ANALYSIS

4.1 INTRODUCTION

The results and data from the research are shown in the study, which are derived from the Plaxis 2D Output. The results will be shown alongside figures of settlement occurred to models after 48 days for non-load and 50 days with applied load. The results of the third and last project's objectives were also covered in this chapter. It will describe the results that were acquired for the objectives with settlement figures, line curves and graphs. This analysis indicates if the objectives will help determine effectiveness of quarry dust as sand replacement in different models created.

4.2 SUBGRADE ANALYSIS

Subgrade analysis were carried out in Plaxis 2D where only material such as clay soil, geotextile separator, sand blanket and embankment fill were utilized in this method called Remove and Replace (RNR). The only variables that will be kept on changing to achieve different outcomes and result through this particular method is raw material in which is called sand. Sand is a key component in ground treatment conducted in Setiu, Terengganu. As such the material itself suffer a lot of consequences involving rise in the price and also limited amount of availability.

Wasted material which is called Quarry Dust were tested through this analysis to replace sand fully or partially in the subgrade of Remove and Replace. These two materials undergo mix ratios to analyse their engineering properties. To perform this analysis, an insight of calculation from post process of Plaxis 2D were conducted such as displacement and settlement particular model. For this analysis, five different models with various different mix ratios were prepared in Plaxis 2D. Table 4.1 indicates different ratios for each model. Model A is the original method used in real method of replace and refill conducted in Setiu, Terengganu. While the other four model of Model B, C, D and E were created as waste material in quarry dust were proposed to partially replace sand in Model B, C D and fully replace Sand in Model E.

Table 4.1: Mix Ratios Used

Model	Sand (%)	Quarry Dust (%)
A	100	0
B	75	25
C	50	50
D	25	75
E	0	100

The amount uses of sand are varying as the width covered for each chainage is different. For this chainage, the distance covered is 300m long involving replace and refill method as the thickness is the only fixed value which is 450mm. For Model A is the thickness is 450mm as the usage of sand is 100%. The thickness is referenced accurately into the model which help to achieve precise data. Other measurements of models are shown in table 2 below.

Table 4.2: Thickness (mm) of Materials

Model	Thickness of Sand (mm)	Thickness of Quarry Dust (mm)
A	450	0
B	337	113
C	225	225
D	113	337
E	0	450

As shown in table 4.2 above, Model A and Model E full utilized each material to see the effectiveness of quarry dust to see if the latter can achieve similar result to Model A which using the original design. While Model C, D and E will showcase if sand and quarry dust can also attain similar or even greater result to Model A.

4.3 TOTAL DISPLACEMENT DATA

The models were simulated in Plaxis 2D software with loads of 0kN and 10kN. The point of curves was also divided into three nodes for displacement which is Point Z (7,0) and for settlement which are Point X (0,0) and Point Y (3.5,0). The deformation values are analysed through Plaxis 2D software, this collected data is turned into a graph to see a clear difference between each simulation. Figures below are illustrating the geometry and deformation with load applied. The data shown in Figures below is total displacement of Model A, B, C, D and E with and without applied load. The element on the right is the scale of the deformation on the soil. It started from blue with no deformation and red as the highest deformation indicator. It is clear that the deformation is more on the part where the line load is located on reinforcement materials for given subgrade under the embankment. The data that is taken from this figure will be compare with another models.

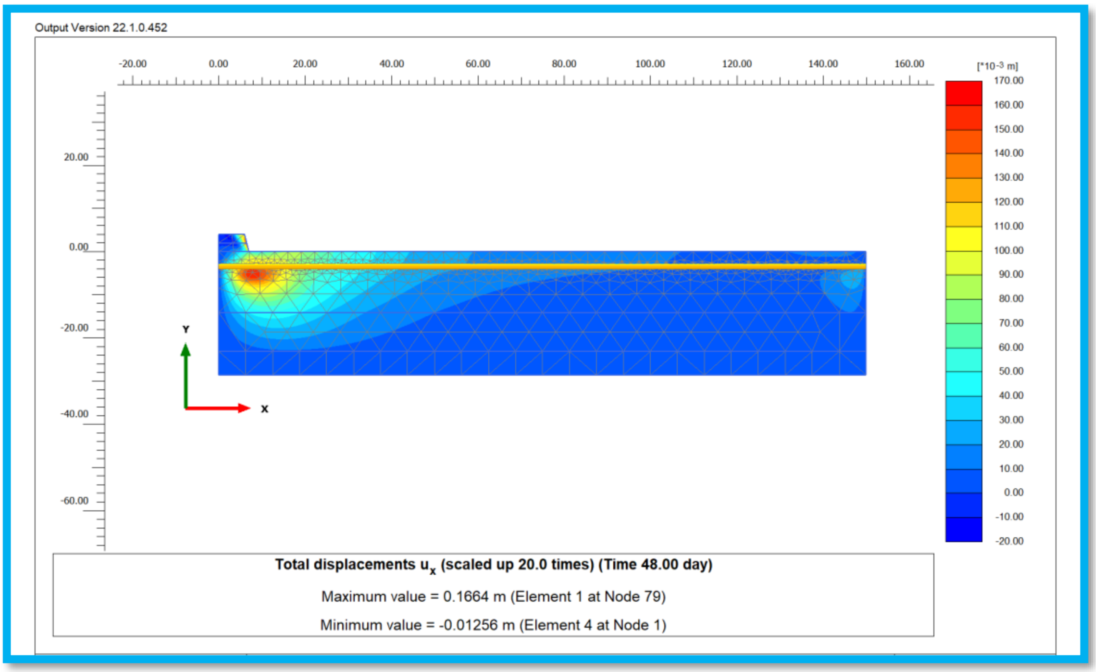

Figure 4.1: Analysis of Displacement in Model A with no load

The data shown in Figure 4.1 is the data of total displacement in the soil as a result of the simulation of 100% sand material with non-load applied to the embankment. The indicator for the elements is the same as deformation of soil occurred at reinforcement materials. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of 0.1664m.

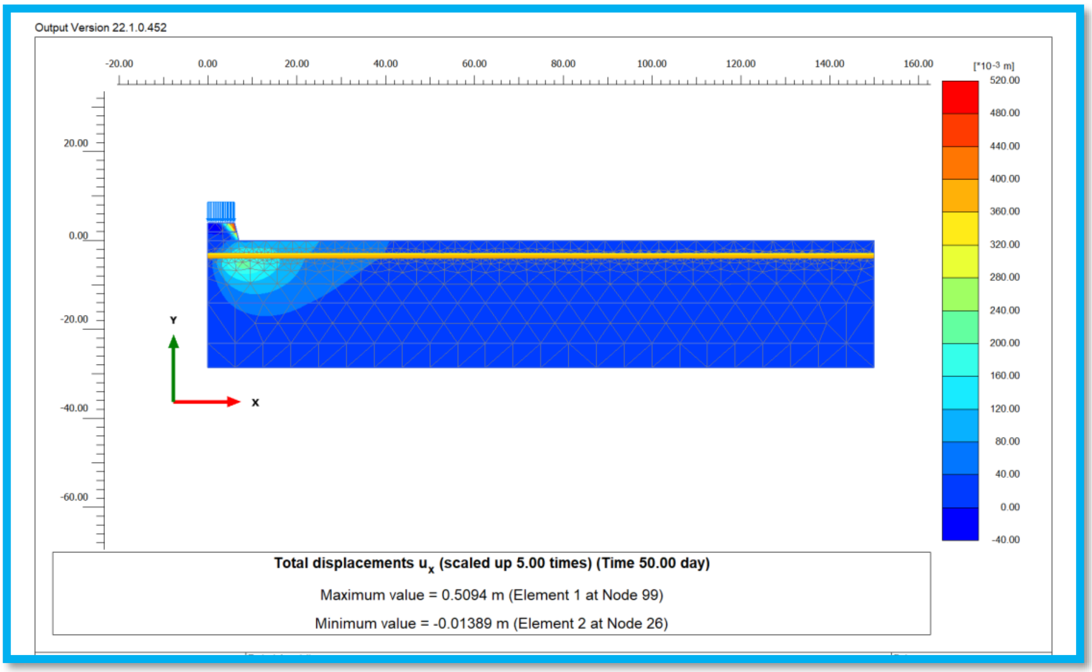

Figure 4.2: Analysis of Displacement in Model A with load (10 kN)

The data shown in Figure 4.2 is the data of total displacement in the soil as a result of the simulation of 100% sand material with applied load of 10kN to the embankment. The indicator for the elements is the different as deformation of soil occurred to the part where the line load located at the slope. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of 0.5094m.

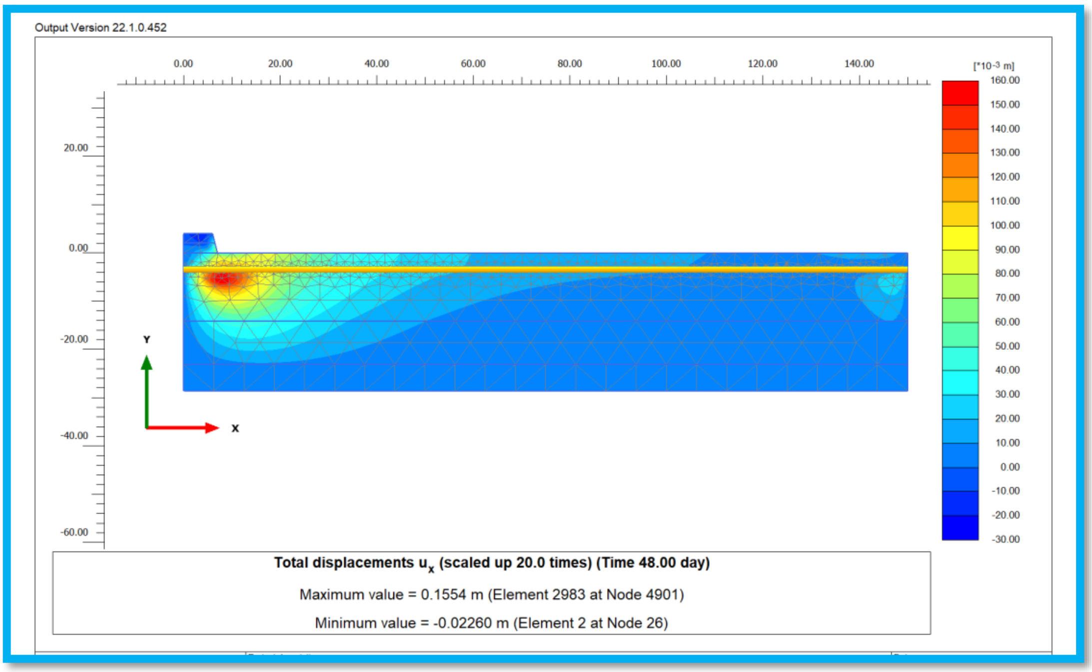

Figure 4.3: Analysis of Displacement in Model B with no load

The data shown in Figure 4.3 is the data of total displacement in the soil as a result of the simulation of 75% sand material and 25% quarry dust with non-load applied to the embankment. The indicator for the elements is the same as deformation of soil occurred at reinforcement materials. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of 0.1554m.

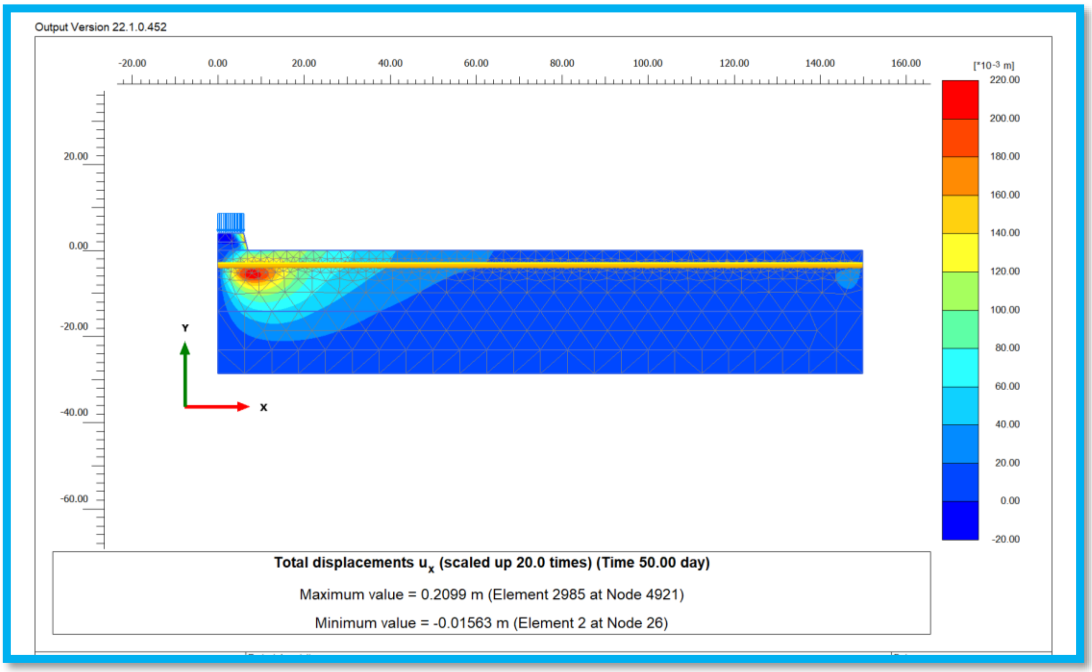

Figure 4.4: Analysis of Displacement in Model B with load (10 kN)

The data shown in Figure 4.4 is the data of total displacement in the soil as a result of the simulation of 75% sand material and 25% quarry dust with applied load of 10kN to the embankment. The indicator for the elements surprisingly different to figure 2 as deformation of soil occurred at reinforcement materials. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of 0.2099m.

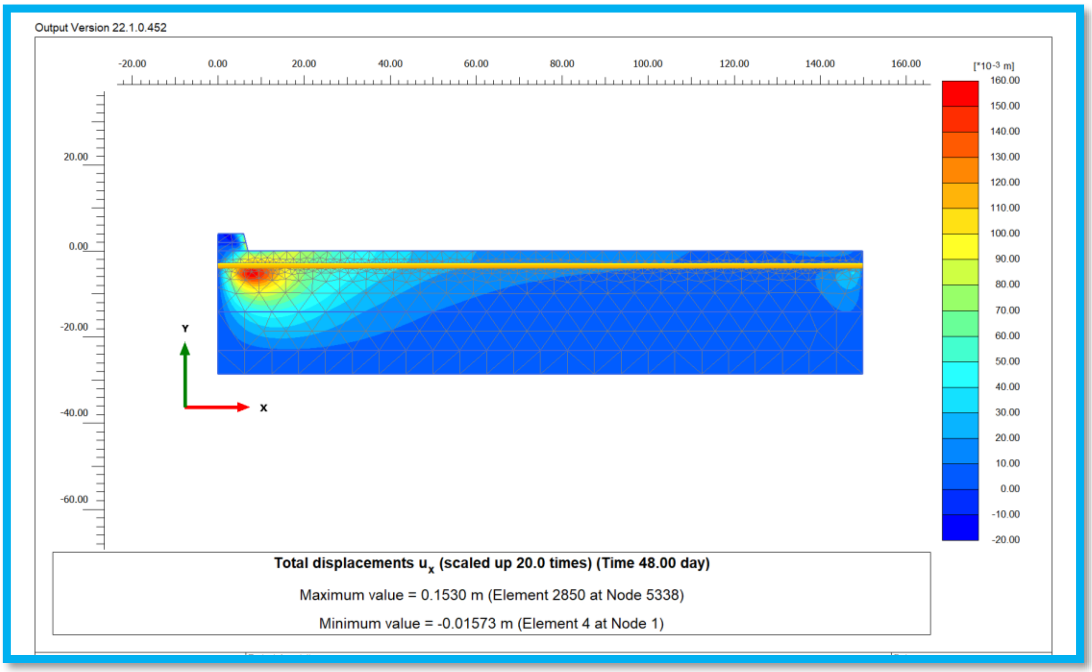

Figure 4.5: Analysis of Displacement in Model C with no load

The data shown in Figure 4.5 is the data of total displacement in the soil as a result of the simulation of 50% sand material and 50% quarry dust with non-load applied to the embankment. The indicator for the elements is the same as deformation of soil occurred at reinforcement materials. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of 0.1530m.

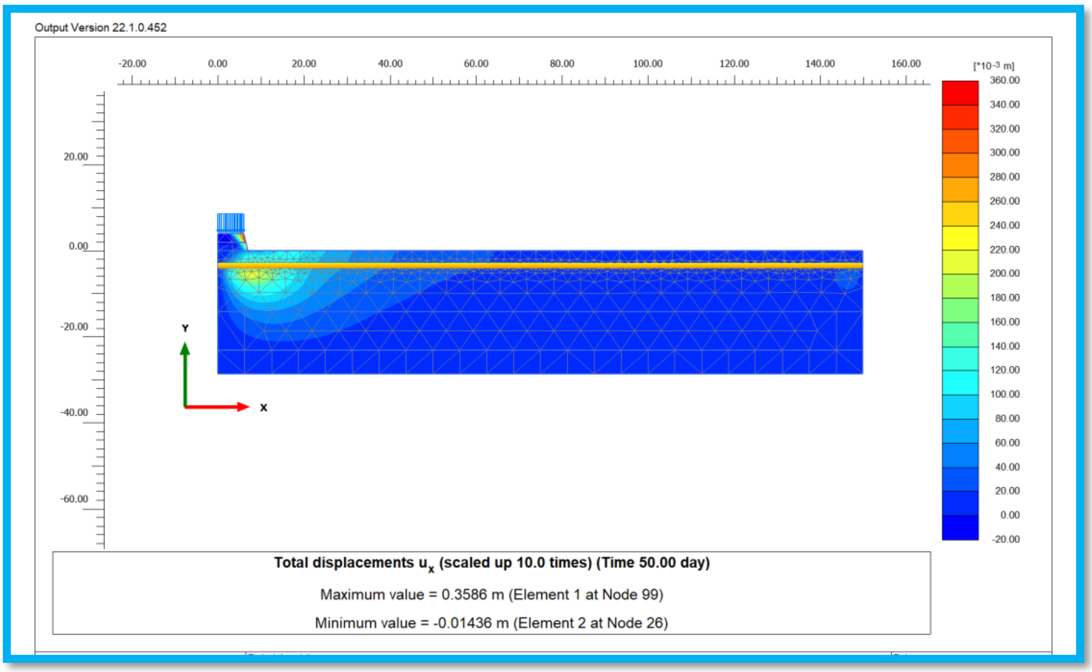

Figure 4.6: Analysis of Displacement in Model C with load (10 kN)

The data shown in Figure 4.6 is the data of total displacement in the soil as a result of the simulation of 50% sand material and 50% quarry dust with applied load of 10kN to the embankment. The indicator for the elements is the different as deformation of soil occurred to the part where the line load located at the slope. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of 0.3586m.

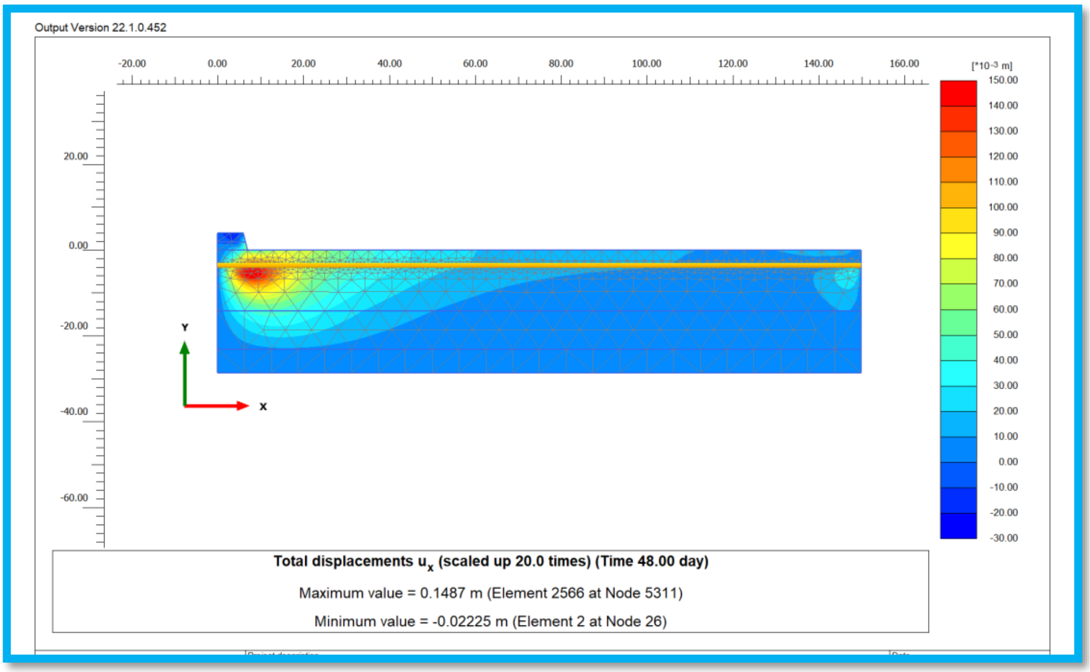

Figure 4.7: Analysis of Displacement in Model D with no load

The data shown in Figure 4.7 is the data of total displacement in the soil as a result of the simulation of 25% sand material and 75% quarry dust with non-load applied to the embankment. The indicator for the elements is the same as deformation of soil occurred at reinforcement materials. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of 0.1487m.

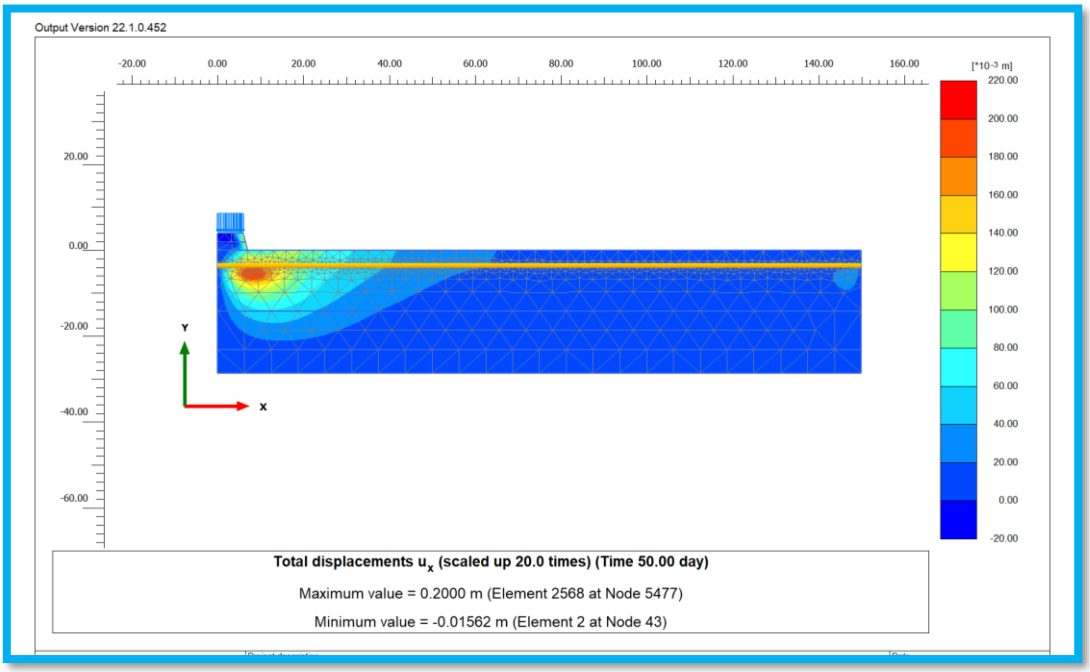

Figure 4.8: Analysis of Displacement in Model D with load (10 kN)

The data shown in Figure 4.8 is the data of total displacement in the soil as a result of the simulation of 25% sand material and 75% quarry dust with applied load of 10kN to the embankment. The indicator for the elements is different to other figures as deformation of soil occurred at reinforcement materials. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of 0.20m.

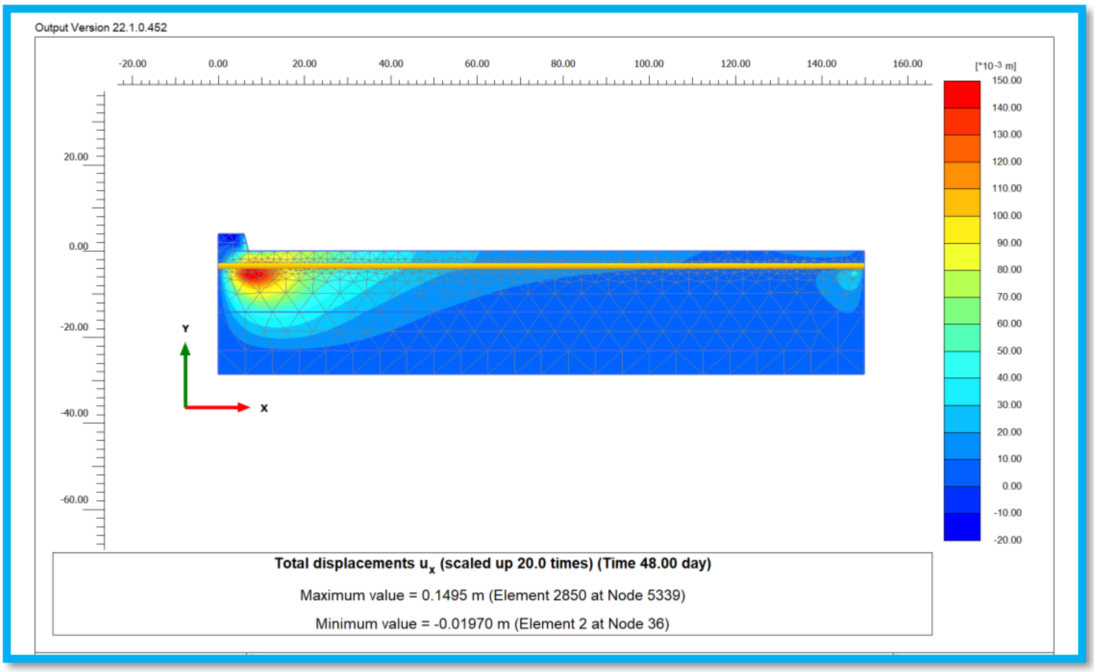

Figure 4.9: Analysis of Displacement in Model E with no load

The data shown in Figure 4.9 is the data of total displacement in the soil as a result of the simulation 100% quarry dust with non-load applied to the embankment. The indicator for the elements is the same as deformation of soil occurred at reinforcement materials. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of 0.1495m.

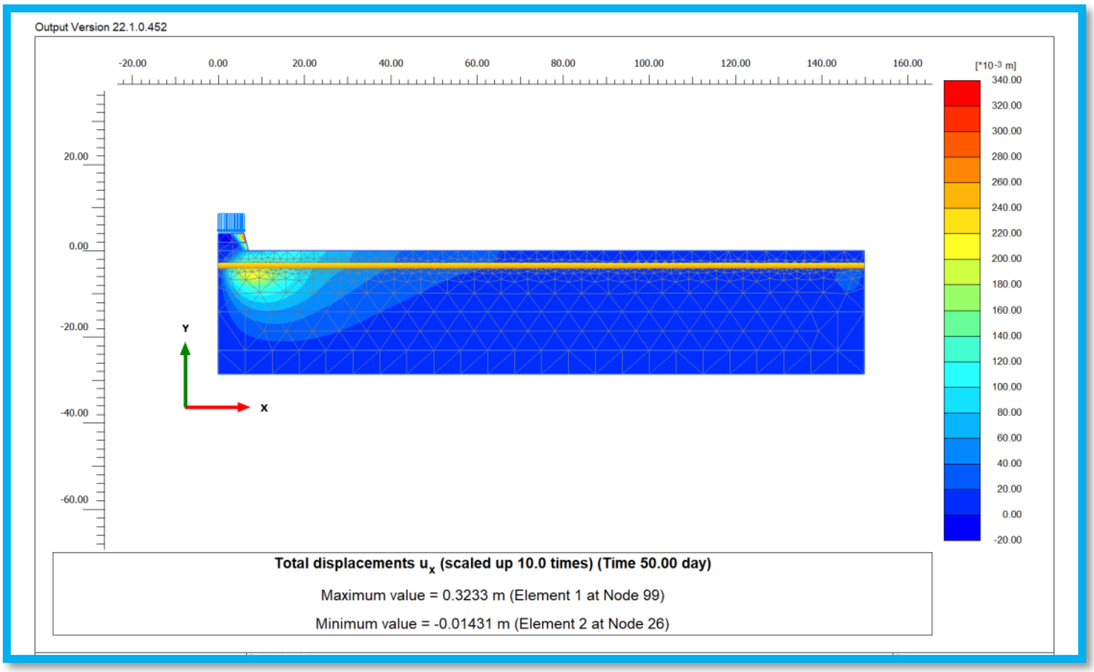

Figure 4.10: Analysis of Displacement in Model E with load (10 kN)

The data shown in Figure 4.10 is the data of total displacement in the soil as a result of the simulation of 100% quarry dust with applied load of 10kN to the embankment. The indicator for the elements is the different as deformation of soil occurred to the part where the line load located at the slope. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of 0.3233m.

4.4 ANALYSIS OF DISPLACEMENT DATA AT POINT Z

This section summaries the findings from simulation and analysis of the subgrade ground improvement model involving reinforcement material in sand and quarry dust conducted using Plaxis 2D software. Point Z (7,0) serve as indicator of particular nodes was analysed for displacement value. The research's findings are presented in numerical form to make them apparent and simple to comprehend.

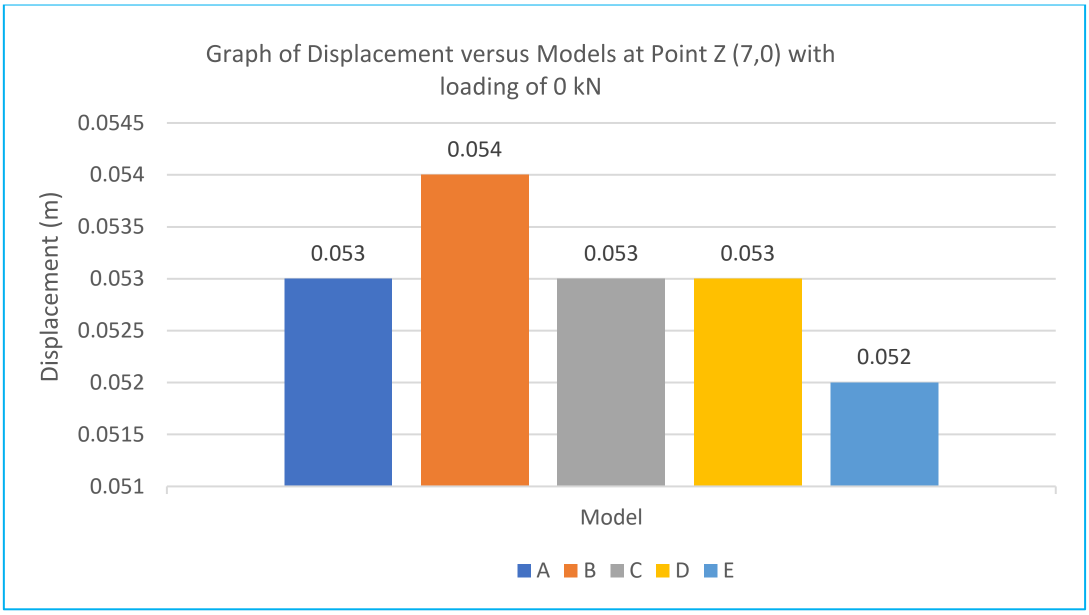

Figure 4.11: Graph of Displacement versus Models at Point Z with 0 kN

Figure 4.11 is the graph data gathered from the simulation of models without load at Point Z (7,0). The displacement will only be observed at Point Z (7,0), which is positioned at the toe of the embankment. This is because the construction of the embankment which begins on a levelled platform would impose stress on the soil after remove and replace. This data act as a medium of comparison to the model of different mix ratios. Without loading applied to the slop, the simulation produced mean of 0.053m of displacement value. The lowest displacement is Model E caused 0.052m of displacement. The displacement caused by the highest load is 0.054m which is Model B Consist of 75% Sand and 25% Quarry Dust.

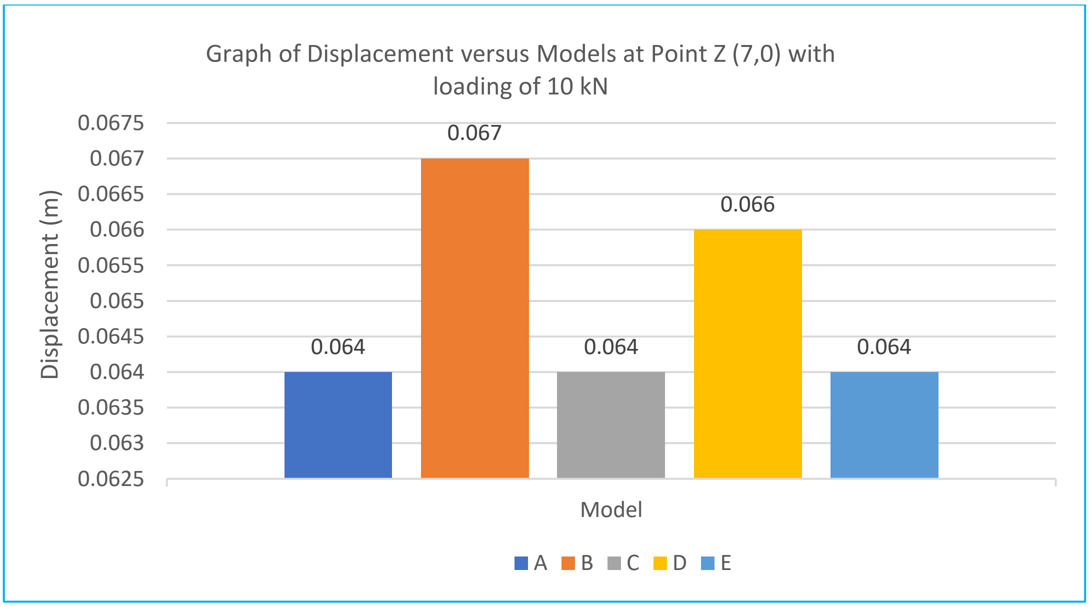

Figure 4.12: Graph of Displacement versus Models at Point Z with 10 kN

Figure 4.12 is the graph data gathered from the simulation of models with load of 10 kN at Point Z (7,0). The displacement will only be observed at Point Z (7,0), which is positioned at the toe of the embankment. This is because the construction of the embankment which begins on a levelled platform would impose stress on the soil after remove and replace. This data act as a medium of comparison to the model of different mix ratios. With loading applied to the slop, the simulation produced mean of 0.065m of displacement value. The lowest displacement is Model A, C and E caused 0.064m of displacement. The displacement caused by the highest load is 0.067m which is Model B Consist of 75% Sand and 25% Quarry Dust.

4.5 TOTAL SETTLEMENT DATA

The models were simulated in Plaxis 2D software with loads of 0kN and 10kN. The point of curves was also divided into three nodes for displacement which is Point Z (7,0) and for settlement which are Point X (0,0) and Point Y (3.5,0). Figures of total settlement involving five different models were shown below before the graph of soil settlement is plotted for all model sets. It is then categorised and merged into five different graphs placed side by side, with the first being Model A until lastly Model E. The element on the right is the scale of the settlement on the soil.

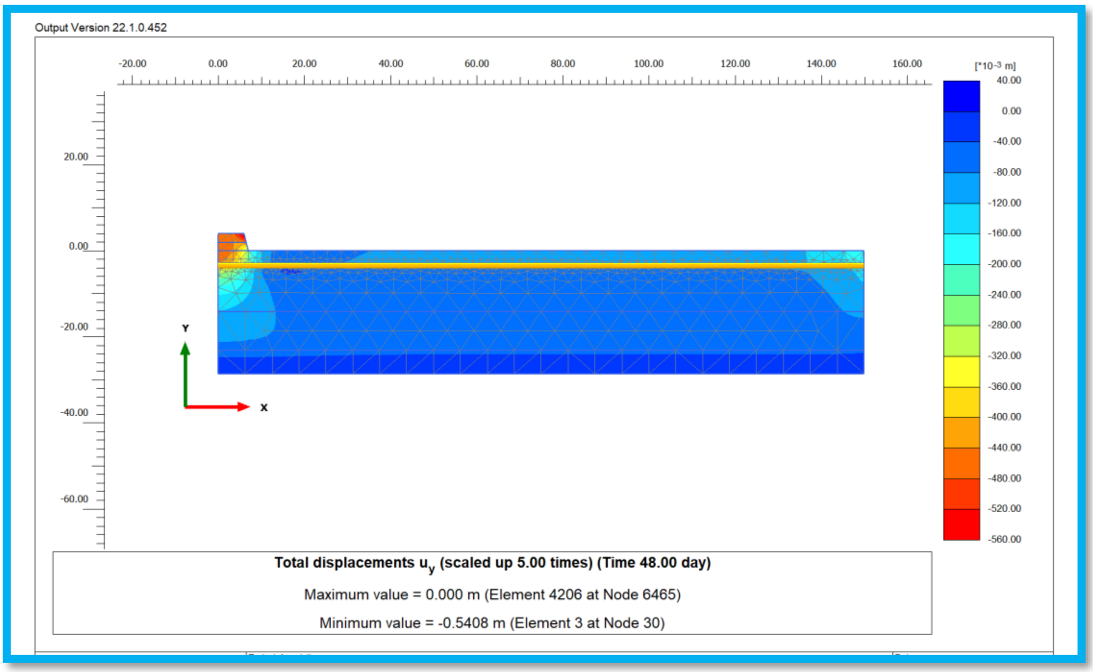

Figure 4.13: Analysis of Settlement in Model A with no load

The data shown in Figure 4.13 is the data of total settlement in the soil as a result of the simulation of 100% sand material with non-load applied to the embankment. The indicator for the elements happens on the embankment across the slope above the subgrade which involving reinforcement materials. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the minimum settlement of -0.5408m.

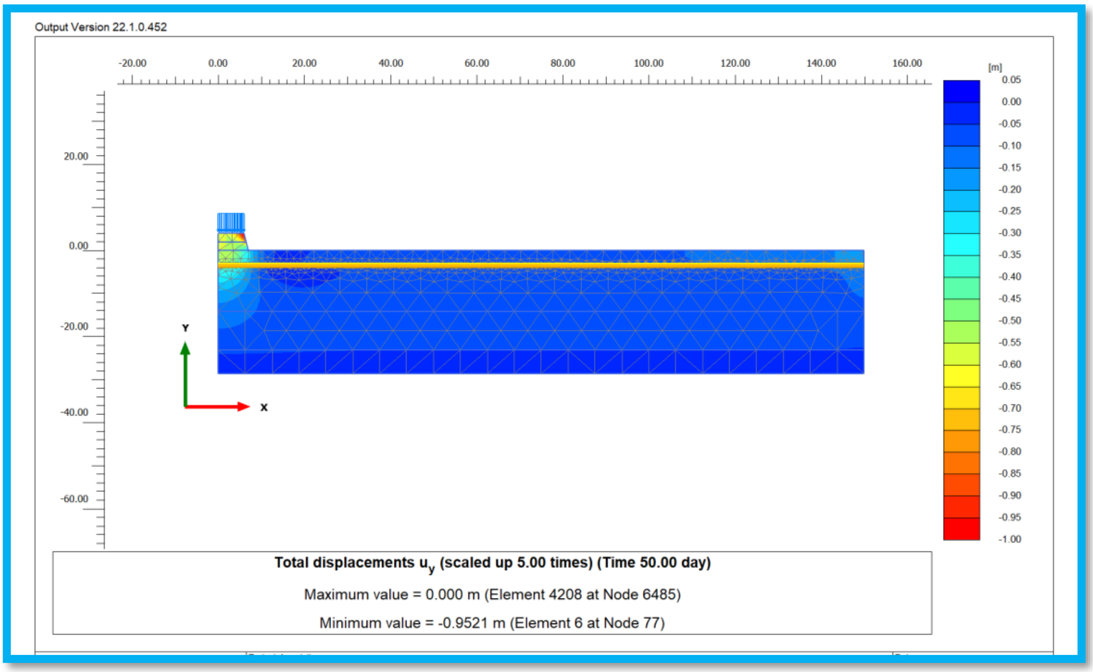

Figure 4.14: Analysis of Settlement in Model A with load (10 kN)

The data shown in Figure 4.14 is the data of total settlement in the soil as a result of the simulation of 100% sand material with applied load of 10kN to the embankment. The indicator for the elements is the different as settlement of soil occurred to the part where the line load located at the slope. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the minimum settlement of -0.9521m.

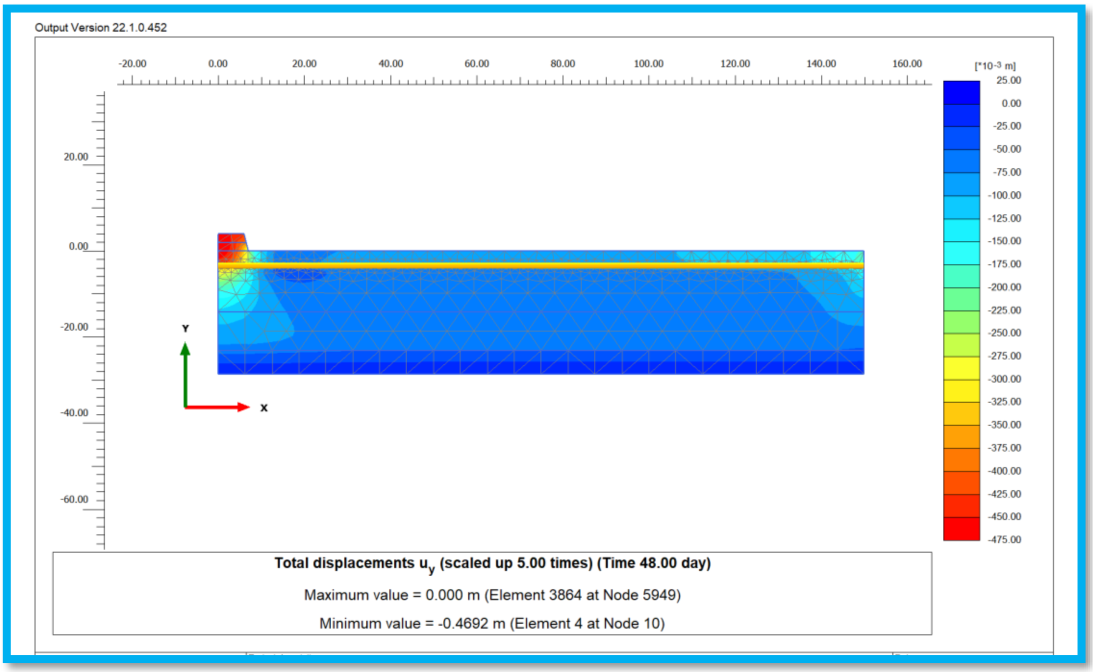

Figure 4.15: Analysis of Settlement in Model B with no load

The data shown in Figure 4.15 is the data of total settlement in the soil as a result of the simulation of 75% sand material and 25% quarry dust with non-load applied to the embankment. The indicator for the elements is the same as settlement of soil occurred entirely across the area of embankment. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the minimum settlement of -0.4692m.

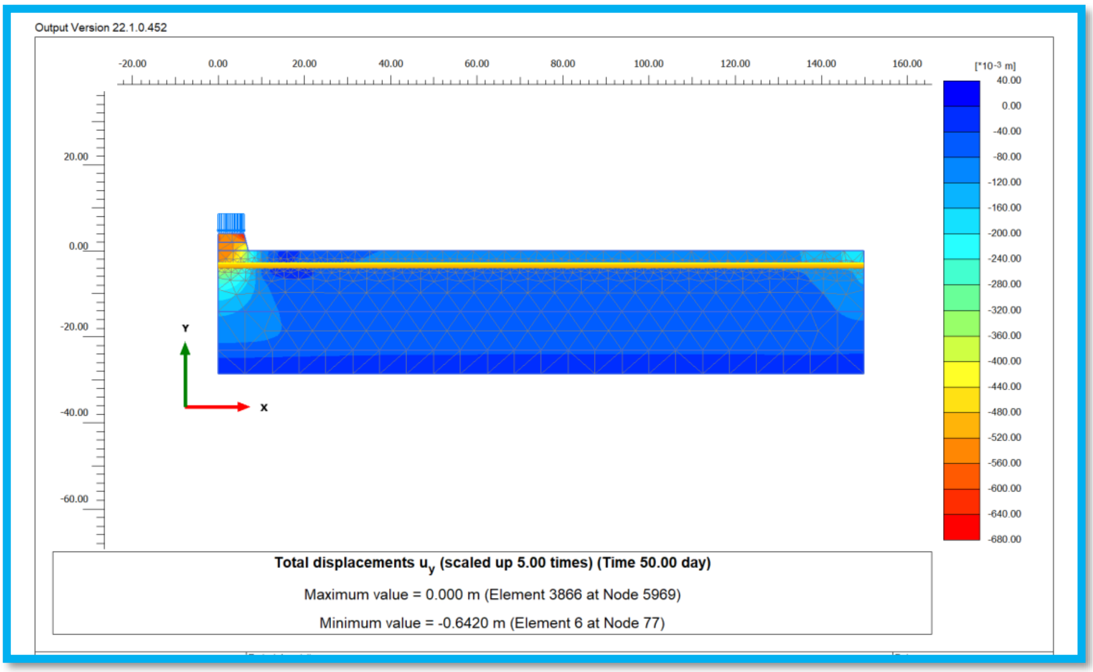

Figure 4.16: Analysis of Settlement in Model B with load (10 kN)

The data shown in Figure 4.16 is the data of total settlement in the soil as a result of the simulation of 75% sand material and 25% quarry dust with applied load of 10kN to the embankment. The indicator for the elements suggesting that the settlement of soil occurred entirely across the area of embankment. The subgrade reinforcement is indicated by the yellow line The data that is taken from the figure is the minimum settlement of -0.4853m.

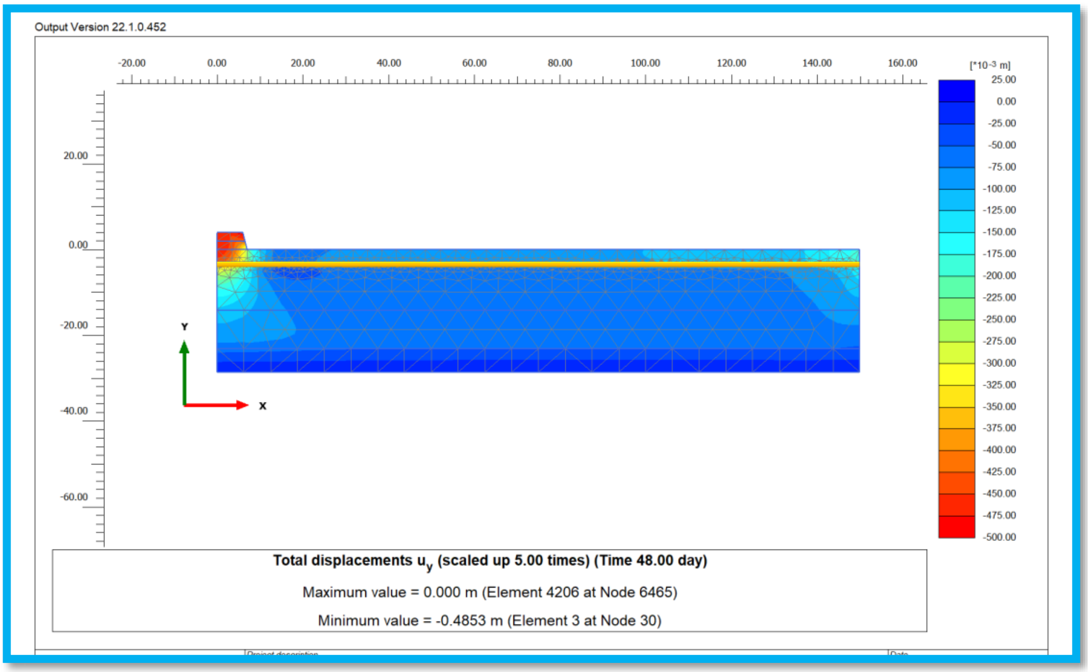

Figure 4.17: Analysis of Settlement in Model C with no load

The data shown in Figure 4.17 is the data of total settlement in the soil as a result of the simulation of 50% sand material and 50% quarry dust with non-load applied to the embankment. The indicator for the elements is the settlement of soil occurred entirely across the area of embankment. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of -0.4853m.

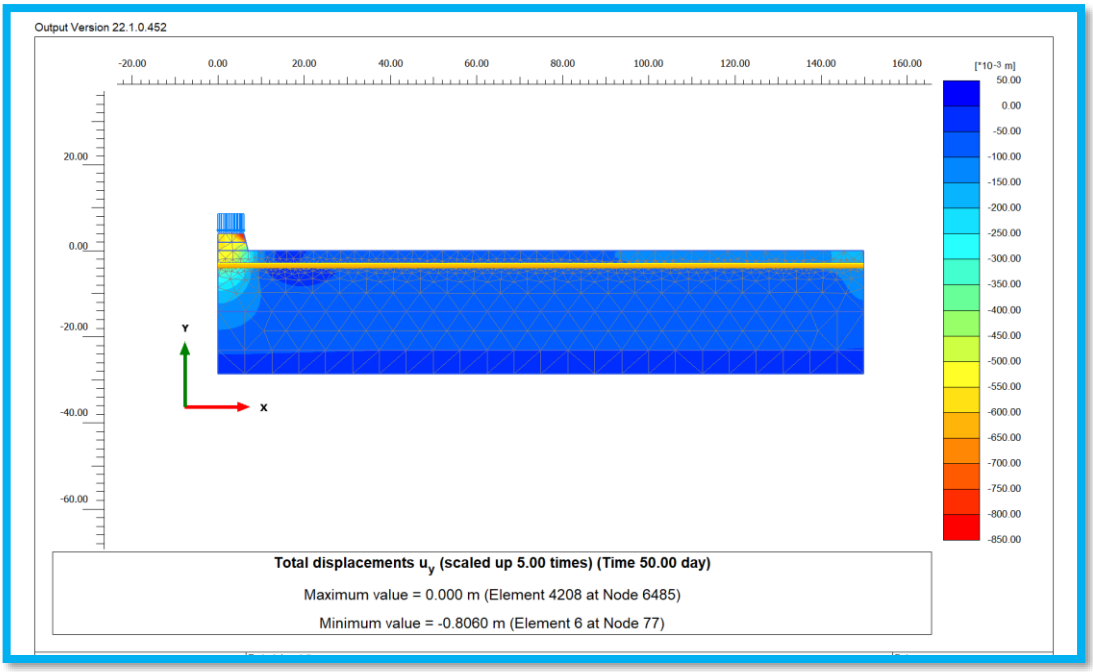

Figure 4.18: Analysis of Settlement in Model C with load (10 kN)

The data shown in Figure 4.18 is the data of total settlement in the soil as a result of the simulation of 50% sand material and 50% quarry dust with applied load of 10kN to the embankment. The indicator for the elements suggesting that the settlement of soil occurred to the part where the line load located at the slope. The subgrade reinforcement is indicated by the yellow line The data that is taken from the figure is the minimum settlement of -0.8060m.

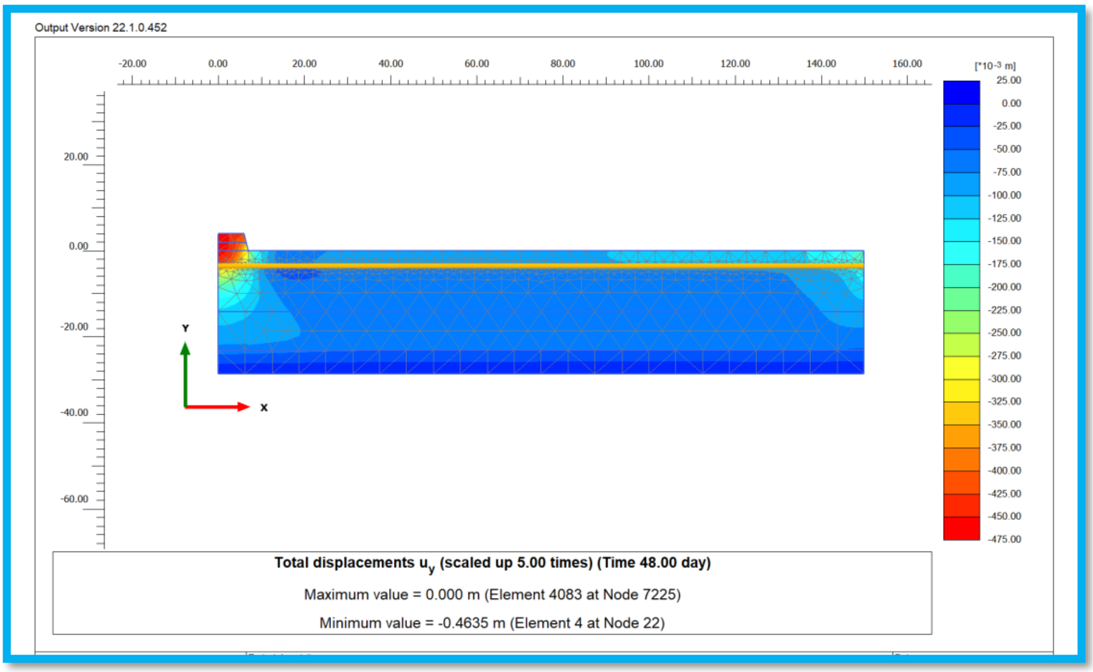

Figure 4.19: Analysis of Settlement in Model D with no load

The data shown in Figure 4.19 is the data of total settlement in the soil as a result of the simulation of 25% sand material and 75% quarry dust with non-load applied to the embankment. The indicator for the elements is the settlement of soil occurred entirely across the area of embankment. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of -0.4635m.

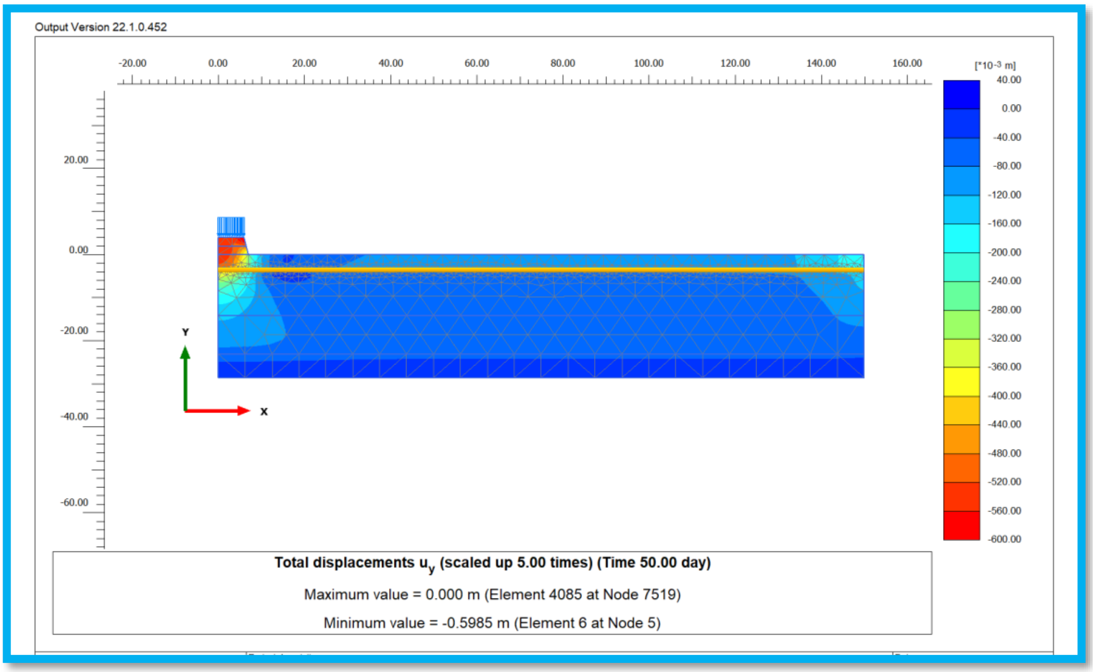

Figure 4.20: Analysis of Settlement in Model D with load (10 kN)

The data shown in Figure 4.20 is the data of total settlement in the soil as a result of the simulation of 25% sand material and 75% quarry dust with applied load of 10kN to the embankment. The indicator for the elements suggesting that the settlement of soil occurred entirely across the area of embankment. The subgrade reinforcement is indicated by the yellow line The data that is taken from the figure is the minimum settlement of -0.5985m.

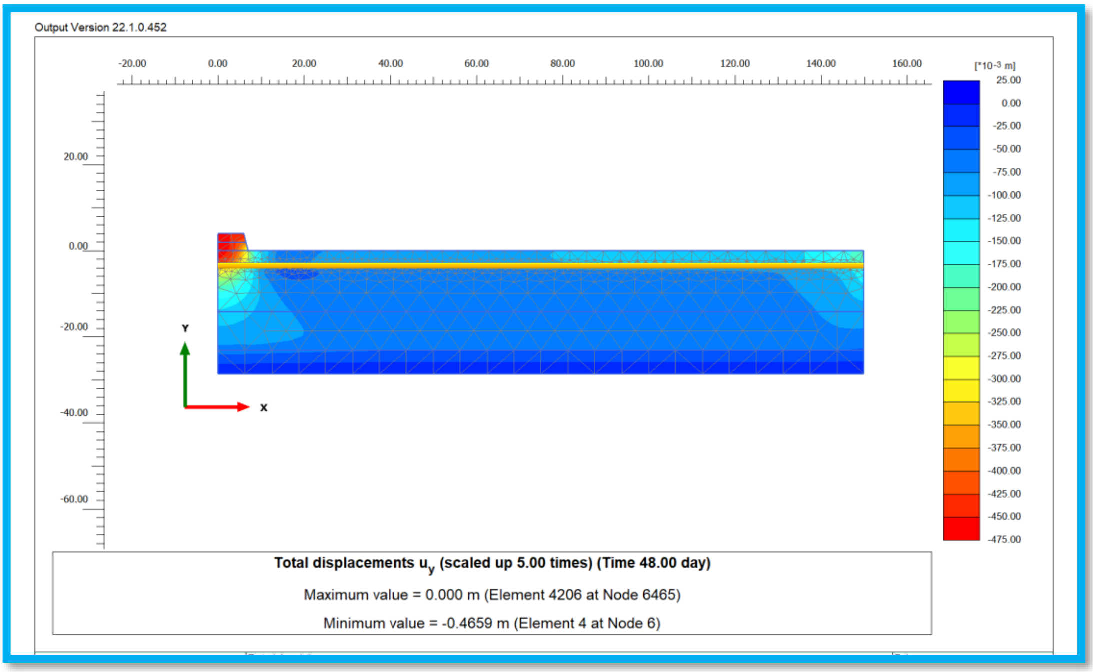

Figure 4.21: Analysis of Settlement in Model E with no load

The data shown in Figure 4.21 is the data of total settlement in the soil as a result of the simulation of 100% quarry dust with non-load applied to the embankment. The indicator for the elements is the settlement of soil occurred entirely across the area of embankment. The subgrade reinforcement is indicated by the yellow line. The data that is taken from the figure is the maximum displacement of -0.4659m.

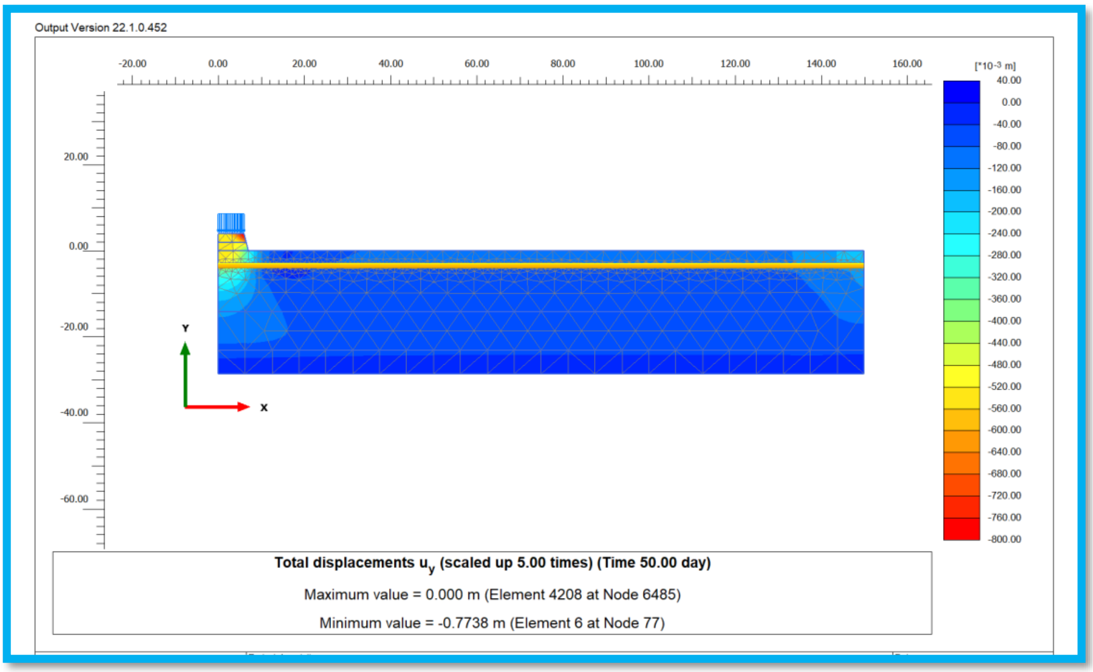

Figure 4.22: Analysis of Settlement in Model E with load (10 kN)

The data shown in Figure 4.22 is the data of total settlement in the soil as a result of the simulation of 100% quarry dust with applied load of 10kN to the embankment. The indicator for the elements suggesting that the settlement of soil occurred to the part where the line load located at the slope. The subgrade reinforcement is indicated by the yellow line The data that is taken from the figure is the minimum settlement of -0.7738m.

4.6 ANALYSIS OF SETTLEMENT DATA AT POINT X

This section summaries the findings from simulation and analysis of the subgrade ground improvement model involving reinforcement material in sand and quarry dust conducted using Plaxis 2D software. Point X (0,0) serve as indicator of particular nodes was analysed for settlement value. The research's findings are presented in numerical form to make them apparent and simple to comprehend.

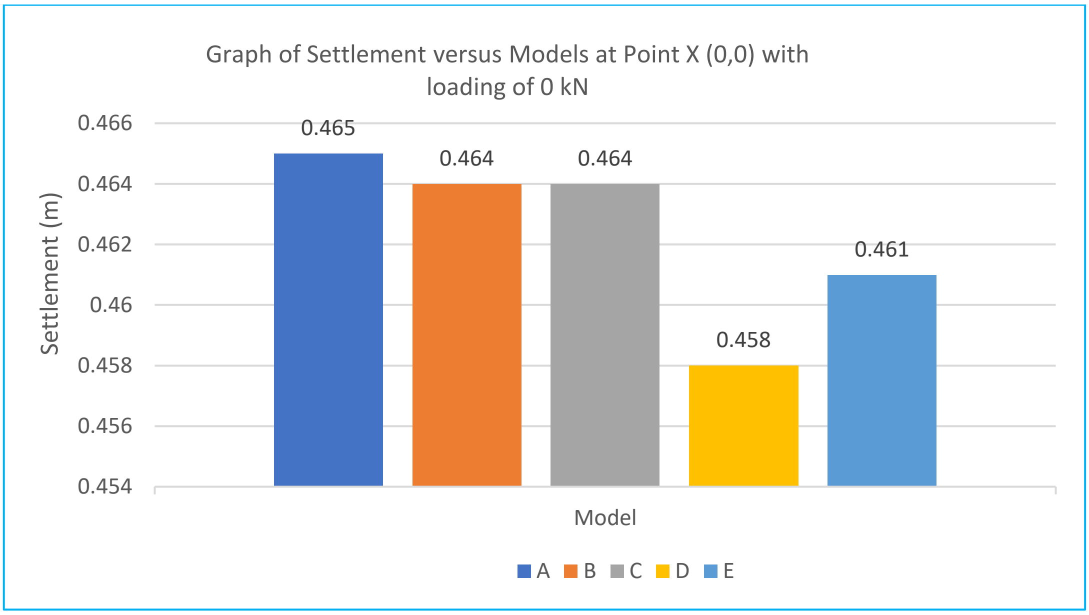

Figure 4.23: Graph of Settlement versus Models at Point X with 0 kN

Figure 4.23 is the graph data gathered from the simulation of models without load at Point X (0,0). The minimum settlement will be observed at Point X (0,0) and Point Y (3.5,0). At point X, which is the midpoint of a full embankment, the settlement of embankment is said to be most critical at the midpoint. This data act as a medium of comparison to the model of different mix ratios. Without loading applied to the slop, the simulation produced mean of 0.462m of settlement value. The lowest settlement is Model D caused 0.458m of settlement. The highest settlement occurred is 0.465m which is Model A Consist of 100% sand.

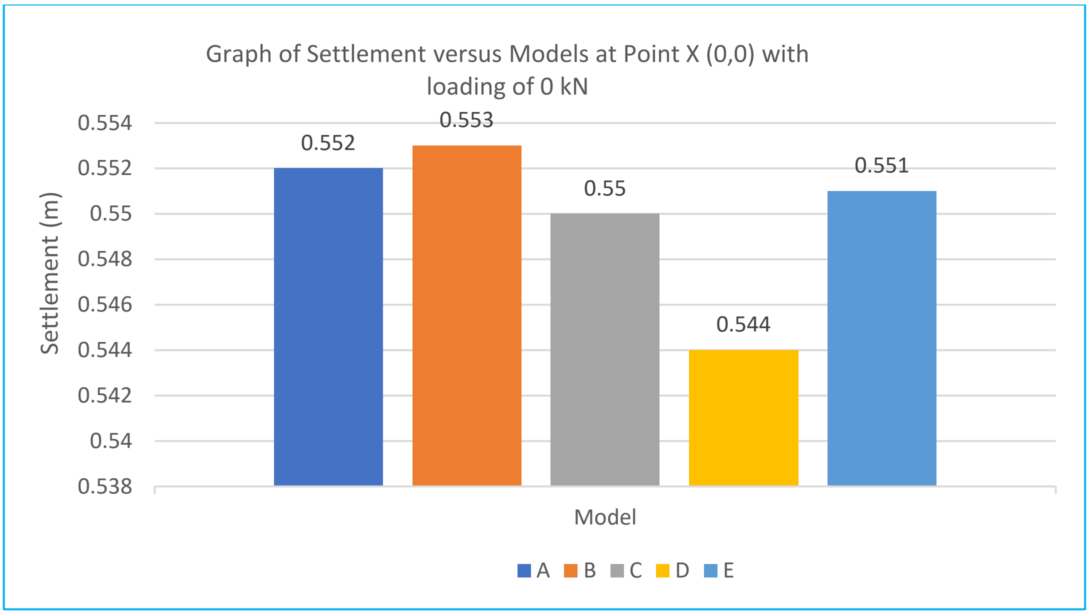

Figure 4.24: Graph of Settlement versus Models at Point X with 10 kN

Figure 4.24 is the graph data gathered from the simulation of models with load of 10kN at Point X (0,0). The minimum settlement will be observed at Point X (0,0) and Point Y (3.5,0). With line loading applied to the slop, the simulation produced mean of 0.550m of settlement value. The lowest settlement is Model D caused 0.544m of settlement. The highest settlement occurred is 0.533m which is Model B Consist of 75% sand and 25% quarry dust.

4.7 ANALYSIS OF SETTLEMENT DATA AT POINT Y

This section summaries the findings from simulation and analysis of the subgrade ground improvement model involving reinforcement material in sand and quarry dust conducted using Plaxis 2D software. Point Y (3.5,0) serve as indicator of particular nodes was analysed for settlement value. The research's findings are presented in numerical form to make them apparent and simple to comprehend.

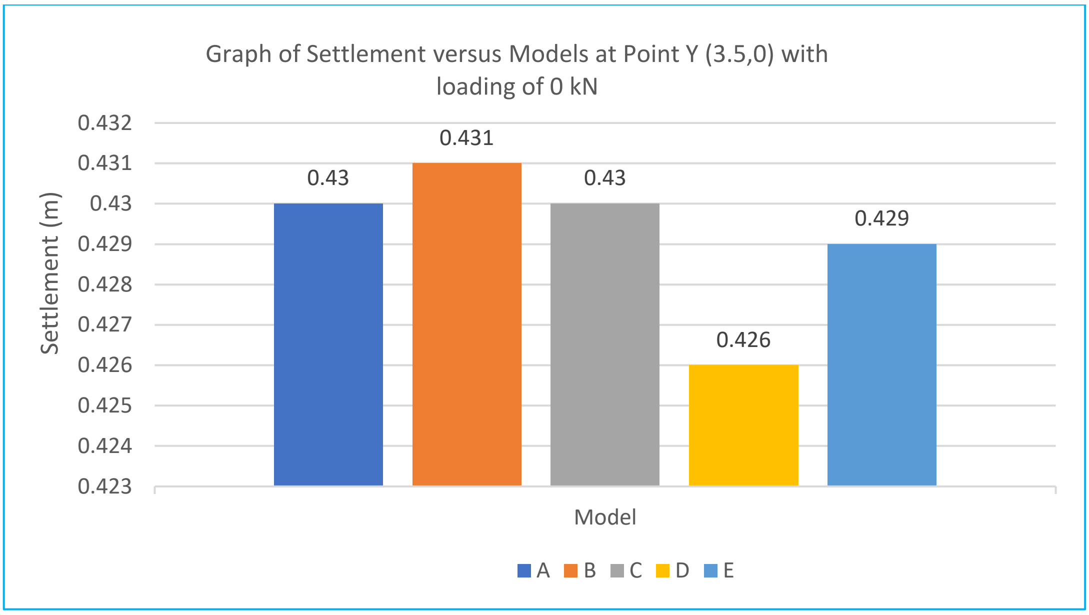

Figure 4.25: Graph of Settlement versus Models at Point Y with 0 kN

Figure 4.25 is the graph data gathered from the simulation of models without load at Point Y (3.5,0). The minimum settlement will be observed at Point X (0,0) and Point Y (3.5,0). At point Y, the overall final settlement for all models is expected to be lesser than that in previous point X. This is due to the embankment's tendency to settle and bend into a "outspread-U-shape" as load is applied to it. As a result, the further the observation analysis is from Point X, the less likely it is to undergo greater settlement than the midpoint of the embankment as can be seen from bar chart in figures above. This data act as a medium of comparison to the model of different mix ratios. Without loading applied to the slop, the simulation produced mean of 0.429m of settlement value. The lowest settlement is Model D caused 0.426m of settlement. The highest settlement occurred is 0.431m which is Model B Consist of 75% sand and 25% quarry dust.

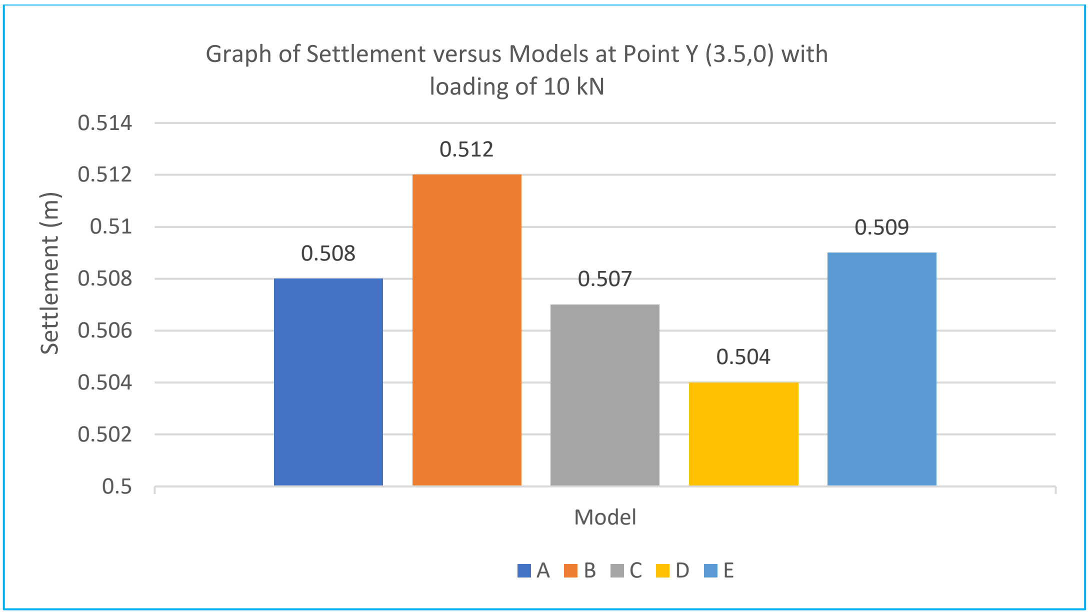

Figure 4.26: Graph of Settlement versus Models at Point Y with 10 kN

Figure 4.26 is the graph data gathered from the simulation of models with load of 10kN at Point Y (3.5,0). The minimum settlement will be observed at Point X (0,0) and Point Y (3.5,0). At point Y, the overall final settlement for all models is expected to be lesser than that in previous point X. This data act as a medium of comparison to the model of different mix ratios. With line loading applied to the slop, the simulation produced mean of 0.508m of settlement value. The lowest settlement is Model D caused 0.504m of settlement. The highest settlement occurred is 0.512m which is Model B Consist of 75% sand and 25% quarry dust.

4.8 CONCLUSION

In conclusion, data analysis is an essential part of all academic and business endeavours. To get insights and make wise judgements, it entails gathering, analysing, and interpreting data. The methodologies and tools employed, as well as the knowledge and experience of the analyst, all affect the quality and accuracy of data analysis. Plaxis 2D enable user to invent answers to many situational issues in geotechnical scope. As such in these analysis, displacement and settlement were put as indicatives to see how models involving quarry dust can attain similar result if not better than the original model which capitalized sand fully as subgrade reinforcement material. From all the models above, Model D serve as the most suitable ways in capitalizing usage of waste material while also making sure similar and sustainable method were achieved by completing all the objectives needed.

CHAPTER 5

DISCUSSION, RECOMMENDATION AND CONCLUSION

5.1 INTRODUCTION

This chapter's data analysis was used to generate the results, conclusions, and recommendations in this section. By assessing the degree to which a particular research aim was accomplished, it was possible to measure the effectiveness of Plaxis 2D in analysing geotechnical issue. Sand and quarry dust plays a key role in making sure this research analysis can be done as one of the major problems is creating solution in reducing the usage of sand while also optimize any qualified waste material. Quarry dust was choose given that this material was frequently dispose near the office and site as the location of proposed ground treatment was near to rock quarry.

The available design also poses a problem given the length of project conducted is 30km and for this selected area, the chainage construction area is 300m. Moreover, sand need to be layout covering up the whole area up to 0.45m. The design itself need alteration as the inclusion of quarry dust give ways how sand can be slightly reduced if not fully. By having desired outcome from the analysis, thus treating the lack of implementation of Geotechnical Analysis Software among Work Department in modern society more seriously.

Not just that, nowadays in this modern era, Industrial Revolution (IR 4.0) rapid rise in innovation has produced an innovative model for education for the future, which necessitates the use of technology in construction as projects become more complex, budget and schedule pressures increase, and quality potentials rise. The use of technology in the construction trade should be increased as it accelerates development, increases productivity, and saves time especially when try to implement new method on-site which can bring risky result without proper research first.

5.2 DISCUSSION

The result of the subgrade ground improvement analysis shows that all the objectives has been achieved. By focusing on material parameters shows how important is by doing deep research and understanding past project related to Plaxis 2D in order to get crucial properties of each single materials in the models. Material such as sand and quarry dust need to be accurate without randomly entering its value as Plaxis 2D demand correct properties, so the outcome result shows error-free data.

The design created involving five different model to be analysed and discussed as to introduce quarry dust in the mix hence why these five models will be tested for simulation to whether the materials can achieve similar result to the original one that was created in Model A. The outcome from all model sets is determined and discussed in which the best model set in terms of minimum settlement reduction and maximum displacement is deduced thus covering the last objectives for this analysis.

The outcome of the simulation has consistent trend in terms of all the manipulative variable of this study. Almost all models were able to produce similar results even when having the presence of quarry dust. Model E which contains 100% quarry dust is favourable over other models as it manages to hold less amount of displacement occurred in Point Z even with load and without load. Meanwhile, Model B which contain few amounts of quarry dust produce the most deformations within with and without load.

Furthermore, for settlement measure, Model D is much effective in minimum vertical settlement. With the model consistently has the least amount of settlement occurred in Point X and Point Y of this analysis. This goes to show how material such as sand and quarry dust can indeed coexist as subgrade reinforcement with the help of geotextile separator. Above all, Model D is deduced to be the best model set in minimum settlement and displacement reduction as the model was still able to achieve in similar result in comparison to the original model.

5.3 CONCLUSION

In conclusion, soft soils are one of the major sources of engineering issues that are derived from excessive settlement of the soil during and after construction phases as this soil have high compressibility and porosity. It is an obligation to think of a way on treating this immediately hence why remove and replace is always the go to method as it is cost saving and easy. Thus, it is unavoidable that sand will still play a major role in many years to come. River mining has become regular way to earn free sand hence why it can impact the environment in a bad way.

Quarry dust is an underutilised waste material that requires care because its characteristics are nearly identical to sand. Quarry dust has shown to be an effective partial substitute for sand, allowing the company to save money on ordering sand, which is highly expensive in today's market. Companies may now reduce waste material on-site by simulating in the programme, allowing them to make better business decisions and produce more revenue in the future. Finally, capable of meeting the requirements of Industry 4.0 (IR 4.0), which is incredibly relevant and increasingly vital for any organisation today.

5.4 RECOMMENDATION

However, continuous research and studies have to be done in order to find a better solution at all times to counter all the problem faced as stated before in this analysis. As such laboratory testing still need to be carried out even when Plaxis 2D has verified how quarry dust can bring advantageous as alternatives to sand. By replicating these five models as prototype in and conduct proper investigation using various implementation.

Next in Plaxis 2D, there have been many other options in soil model that can still be implemented to get different reaction out of the analysis. Model such as Modified Cam Clay, Hardening Soil and Linear Elastic can be used to try and see whether the result is even better than conducted.

Moreover, various calculation type is available to get other output data as measurement such as safety factor and pore water pressure. Plaxis 2D enabled the user to be creative as much by changing the conventional design by making more safe and effective subgrade design itself when proposing sand-quarry dust model. Thus, an authentic source can support the study's findings and data.

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r=2013&journal=Indian+streams+Res.+J.&volume=3&pages=1%E2%80%938

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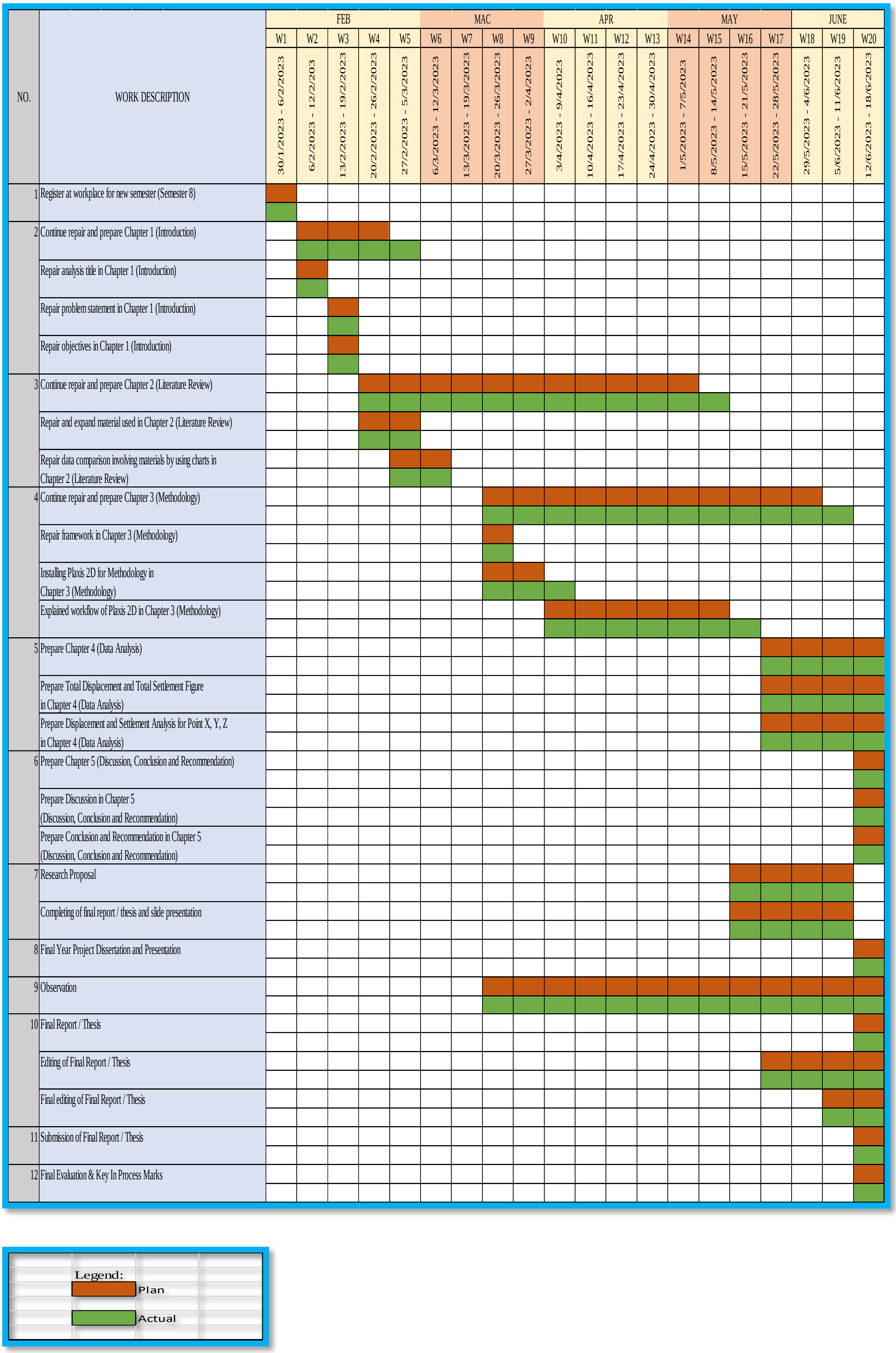
APPENDIX 1

GANTT CHART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8/5/2023 - 14/5/2023
15/5/2023 - 21/5/2023
22/5/2023 - 28/5/2023
29/5/2023 - 4/6/2023
5/6/2023 - 11/6/2023
12/6/2023 - 18/6/2023
1 Register at workplace for new semester (Semester 8)
2 Continue repair and prepare Chapter 1 (Introduction)
Repair analysis title in Chapter 1 (Introduction)
Repair problem statement in Chapter 1 (Introduction)
Repair objectives in Chapter 1 (Introduction)
3 Continue repair and prepare Chapter 2 (Literature Review)
Repair and expand material used in Chapter 2 (Literature Review)
Repair data comparison involving materials by using charts in Chapter 2 (Literature Review)
4 Continue repair and prepare Chapter 3 (Methodology)
Repair framework in Chapter 3 (Methodology)
Installing Plaxis 2D for Methodology in Chapter 3 (Methodology)
Explained workflow of Plaxis 2D in Chapter 3 (Methodology)
5 Prepare Chapter 4 (Data Analysis)
Prepare Total Displacement and Total Settlement Figure in Chapter 4 (Data Analysis)
Prepare Displacement and Settlement Analysis for Point X, Y, Z in Chapter 4 (Data Analysis)
6 Prepare Chapter 5 (Discussion, Conclusion and Recommendation)
Prepare Discussion in Chapter 5 (Discussion, Conclusion and Recommendation)
Prepare Conclusion and Recommendation in Chapter 5 (Discussion, Conclusion and Recommendation)
7 Research Proposal
Completing of final report / thesis and slide presentation
8 Final Year Project Dissertation and Presentation
9 Observation
10 Final Report / Thesis
Editing of Final Report / Thesis
Final editing of Final Report / Thesis
11 Submission of Final Report / Thesis
12 Final Evaluation & Key In Process Marks
Legend:
Plan
Actual

APPENDIX 2

REMOVE AND REPLACE GROUND TREATMENT PROGRESS


SANY