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The Study of Deep Soil Mixing for Ground Treatment in Section 1 For East Coast Rail Link (ECRL) Project During Construction Phase

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Abstract: Deep soil mixing (DSM) is a ground improvement technique commonly used to address challenges associated with soft clay soil. Soft clay soil covers vast areas in many countries, making it difficult to find suitable locations for construction. DSM has emerged as an effective method to enhance the soil surface before commencing construction activities. This study focuses on the application of DSM in the context of the East Coast Rail Link (ECRL) project, which involves the construction of a tunnel, subgrade, and other associated structures. The primary objectives of the design process for cement-soil columns, a key component of DSM, is to improve the qualities of local soils, such as strength and stiffness, by incorporating various cementing materials. Two approaches are commonly employed in the process of deep soil mixing which is dry method and wet method. For the construction of railway embankments in the ECRL project, the wet approach was chosen. Analysing the difference between theoretically measured coordinates and the actual coordinates obtained after implementing the DSM activity played a crucial role in this method. Prior to implementing the deep soil mixing procedures, laboratory tests were conducted to assess the soil characteristics and determine the appropriate deep soil mixing techniques for specific soil types. It emphasizes the importance of laboratory testing, the selection of appropriate DSM techniques, and the evaluation of outcomes to ensure successful soil improvement. At the end of the research that was done for this project, it was determined that the DSM approach is the way that is best suited to improve the structure and condition of the soil in preparation for the construction of a large-scale project. Because of this, it was discovered that the DSM approach is effective at recovering stability to the surface of the soil, which was previously unstable.

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1. Introduction

This report focuses on ground treatment using deep soil mixing in CH7+360 ~ CH7+410 in section 1 which is in subgrade No. 1. Deep soil mixing (DSM) is a way to improve soft clay soil, which is often used as a base for different buildings. Before building, it is very important to find out how strong the dirt is. DSM is an effective way to deal with problems caused by soft clay dirt. The study looks into how DSM works and tries to improve the structure of the dirt. To figure out the qualities of the soil, tests like DSM coring, unconfined compression, and plate bearing are done in the lab. In recent years, DSM has become more popular for stabilising liquefiable and cyclically lowering ground.

2. Deep Soil Mixing (DSM)

Deep soil mixing, often known as DSM, is a method of ground improvement that involves mechanically mixing soft, high-moisture clays, peats, and other weak soils with dry cementitious binder. This helps to enhance the quality of the soil. [1] Deep soil mixing method, also known as DSM, is one of the practical methods of ground improvement technique used around the world. This method for the treatment and enhancement of in-situ soil that involves the use of a hollow stem auger and paddle arrangement for the purpose of mechanically mixing the in-situ soil with cementitious materials that are referred to as binders. This technique, which produces cement soil columns and modifies the characteristics of the soil by injecting stabilising materials like cement or lime into the soil using a mechanically hollow drill, is one of the most effective methods of ground improvement technique. [2]

There are two distinct forms of DSM, namely dry mixing and wet mixing. Injection of binders in the form of a slurry, which is then mixed with the soil is what is meant by "wet mixing." Cement-based slurries are mixed primarily with single-auger, multi-auger, or cutter-based procedures to produce isolated components, continuous walls or blocks for large-scale foundation improvement, earth retaining systems, hydraulic barriers, and contaminant/fixation systems. [3]

In Keller’s deep soil mixing method a special mixing tool is inserted into the soil on site. This mixing tool comprises a drilling rod, transverse beams and a drill end with a head. The drilling does not result in any vibrations and is helped along by the outflow of cement slurry from nozzles that have been purposefully placed at the end of the soil auger. After the depth indicated by the design is attained, the building phase of DSM columns starts. [4]

The coring that was performed, which was then included in the testing samples, was used to determine the result of the deep soil mixing procedure. During the course of these investigations, the contractor participated in two separate rounds of laboratory testing. The unconfined compression test was the first one, and then the plate bearing test came next. Because of the test's focus on strengthening the coring, these two tests were particularly significant to the deep soil mixing procedure.

The Unconfined Compression Test, or UCT for simple terms, is a straightforward laboratory testing procedure that may be used to evaluate the mechanical qualities of fine-grained soils and rocks. It offers a measurement of the rock's or soil's undrained strength as well as its stress-strain properties. In geotechnical investigations, particularly those involving rocks, the unconfined compression test is frequently included in the laboratory testing programme. This is particularly true when the test is being conducted on rocks. [5]

An increasing load from a circular steel plate is used in a plate load test, which is also known as a plate bearing test. This test is used to measure the ground's bearing capacity and real strength by inducing settlement using the rising force from the steel plate. It is utilised in circumstances in which the ground particle sizes are big or the soil has a more rigid consistency. [6]

As the world becomes more urbanised, the conventional technique of construction becomes less suitable. Presently, the construction industry faces formidable obstacles, as construction is required even on porous ground. Soft ground is soil that possesses characteristics such as low undrained shear strength (less than 25 kPa), high compressibility, such as silt deposits, and low permeability. [7]

Figure 1: PH-5D Deep Soil Cement Mixing Pile Driver [8]

Based on the figure 1 shows the PH-5D deep soil mixing pile driver used in this project. Deep soil mixing requires a specialised sort of equipment, and the construction industry makes extensive use of a product known as the PH-5D Deep Soil Cement Mixing Pile Driver.

Figure 2: Automatic Mixer [8]

Based on the figure 2 shows the automatic mixer used for mixing the cement, soil and other binding. When mixing deep soil, the purpose of an automated mixer is to ensure that the soil and cement or other binding agents are thoroughly and uniformly combined.

Figure 3: Grout pump [9]

As shown in figure 3 is the example of grout pump while the works is still on going. In the process of deep soil mixing, a specialised equipment known as a grout pump is utilised to inject a grout mixture into the soil in order to enhance the soil's strength and stability. [9]

3. Methodology

This section observing the deep soil mixing (DSM) process is crucial to ensure it meets standards and specifications, and the treated soil performs as required. Field verification confirms proper column coordinate and adherence to mixing parameters. Site visits, visual inspections, and soil testing are used for observation. D-value is the result of the difference between theoretical coordinate and the actual coordinate. Tests assess soil strength, stiffness, and properties during and after construction. Common tests include unconfined compression test and plate bearing test.

Based on the figure 4 shows the flowchart for a whole project in analysing the deep soil mixing method in ECRL project during construction in Section 1 which is located in Kota Bharu. Along the project was going smoothly due to the planning was made.

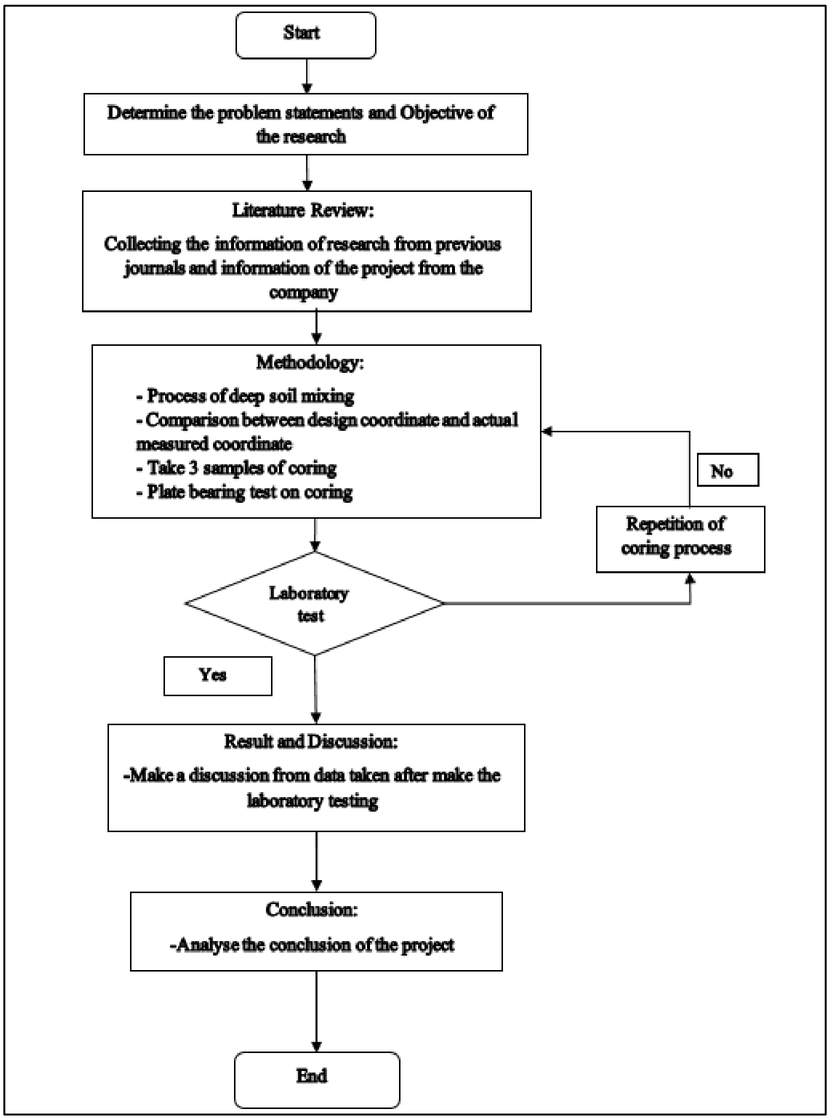

Figure 4: Flow chart of the deep soil mixing

4. Analysis Data and Discussion

Deep soil mixing is used in this project to improve the ground for large-scale construction like the ECRL project. The specific results and discussion of the project depend on objectives, soil conditions, and testing. The technique enhances geotechnical properties, such as shear strength, compressibility, and permeability. Strength tests are performed to assess the increase in strength after deep soil mixing and its impact on load-bearing capacity and stability. Achieved strengths are compared to design criteria or standards to evaluate the effectiveness of the treatment. The result has been recorded based on the laboratory testing.

4.1 Discussion of the process during deep soil mixing (DSM) method

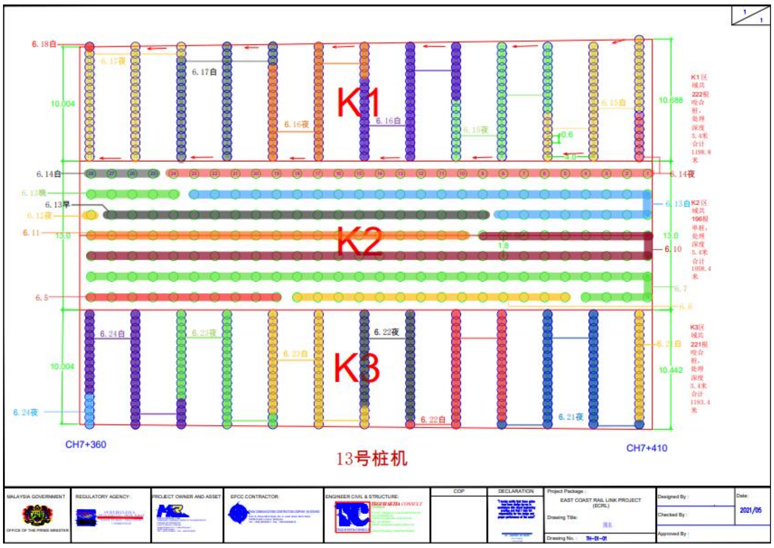

Figure 5: Design coordinate of the DSM

Design coordinates identify precise locations for implementing a soil mixing treatment. The treatment were outlined from area and direct its spatial distribution. Specifying where columns or panels will be installed, design coordinates aid in the planning and organisation of the treatment process. They function as a reference system to assure treatment accuracy and precision. Marking the treatment locations with design coordinates assists equipment operators in applying the treatment with the desired spacing and distribution.

4.2 D-value of design coordinate compared to the actual coordinate

The result of the d-value is determined by comparing the design coordinate to the actual measured coordinate. This comparison allows us to evaluate any deviations between the intended and actual diameters of the treated soil columns. In deep soil mixing, a considerable deviation or variation between the intended and actual diameters of the treated soil columns is indicated by a high result for the difference between the design coordinate and the actual measured coordinate. This elevated value can have a number of repercussions and may necessitate further analysis and corrective action.

4.3 Strengthen test on coring of deep soil mixing method

There is two laboratory testing were conducted which is unconfined compression strength and plate bearing test. Both laboratory tests play essential roles in understanding the behaviour of the soil and determining its suitability for construction purposes. By conducting these laboratory tests, the project team can gather crucial data and insights into the soil's properties and behaviour.

A. DSM coring unconfined compression test

Table 4.1: DSM coring unconfined compression test

Sample no.	1	2	3
Core sample depth, (m)	0 – 2.5	2.5 – 4.0	4.0 – 5.4
Height, L0 (mm)	103	103	103
Diameter, D (mm)	94	94	94
Cross section area, A0 (mm^2)	6936.3	6936.3	6936.3
Maximum axial force, Pm (kN)	29.18	38.73	100.36
Unconfined compressive strength, qu (MPa)	4.2	5.6	14.5
Soil classification	Soft to medium	Soft to medium	Stiff to hard

Table 4.1 shows the test result indicates that the soil specimen had a maximum axial force of 3 samples before failure or significant deformation occurred.

Figure 6: The result of coring sample

Based on the figure 4.1 shows the sample the core sample is continuous, the surface is smooth, the cementation is good, the cement is evenly distributed, the fracture is consistent, and the core recovery rate is more than 90%.

B. Plate bearing test

The plate bearing test is a common geotechnical test used to assess the bearing capacity and settlement behaviour of soils, including those treated with deep soil mixing.

Table 4.2: 1st loading & unloading cycle

	Pressure on ground (kPa)	Pressure on gauge (kPa)	Average settlement (mm)
	0.0	0.0	0.00
	37.5	37.5	1.88
1st loading & unloading cycle	75.0	75.0	2.69
	112.5	112.2	3.95
	150.0	150.0	5.30
	112.5	112.5	5.22
	75.0	75.0	5.09
	37.5	37.5	4.97

Based on the table 4.2 maximum settlement for 1st loading & unloading cycle is 5.30 mm at 150 kPa.

Table 4.3: 2nd loading & unloading cycle

	Pressure on ground (kPa)	Pressure on gauge (kPa)	Average settlement (mm)
2nd loading & unloading cycle	0.0	0.0	4.14
	75.0	75.0	5.04
	150.0	150.0	5.37
	187.5	187.5	6.30
	225.0	225.0	7.44
	150.0	150.0	7.23
	75.0	75.0	6.88
	0.0	0.0	5.77

Based on Table 4.3 shows the maximum settlement for 2nd loading & unloading cycle is 7.44 mm at 225 kPa.

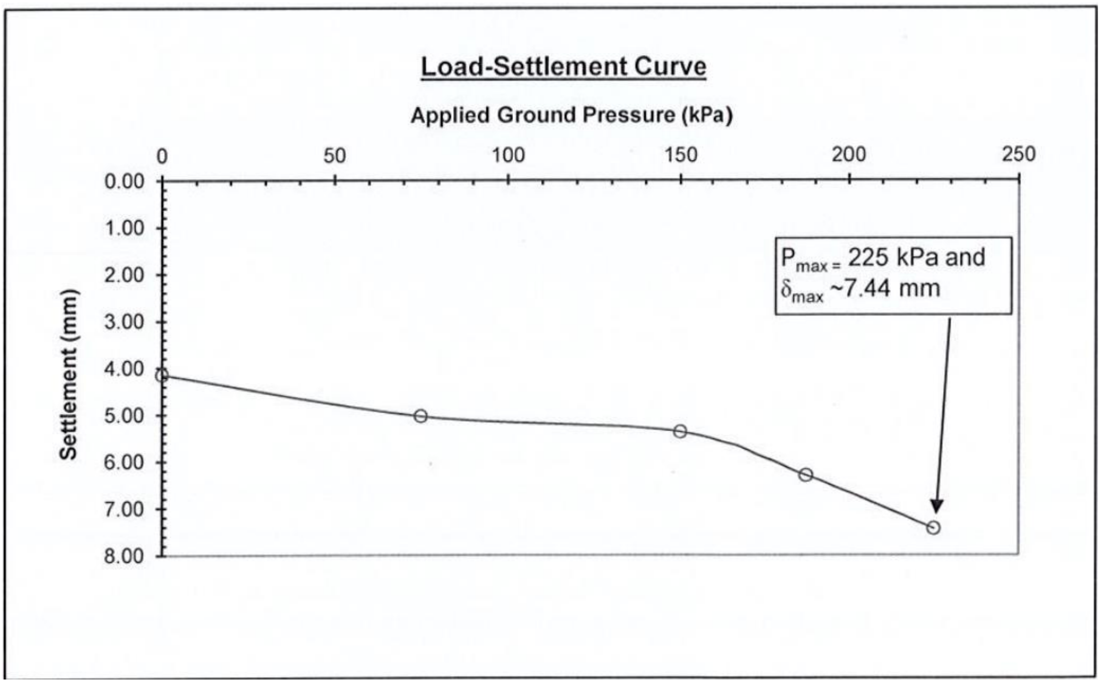

Figure 7: Load settlement curve

Based on Figure 4.3 shows the 225kPa for pressure on ground the maximum settlement is 7.44 mm. This curve shows the relationship between applied load and corresponding settlement of the treated soil.

5. Conclusion

In summary, the statement indicates that the goals of ground treatment by deep soil mixing were effectively accomplished. The fact that the final result was unaffected by the technique demonstrates that the project was successful in meeting its objectives, despite the decreased failure rate that occurred throughout the procedure. When favourable results are obtained, this indicates that the deep soil mixing approach has been effective in successfully enhancing the soil and satisfying the criteria for the project.

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