

# Investigation on Strength Development in RBI Grade 81 Stabilized Serian Soil with Microstructural Considerations

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**Abstract.** The aim of the research is to investigate the strength development of stabilised local Serian soil with RBI Grade 81 a chemical additive to enhance soil properties in term of strength. Serian is a town which is located about 60 km from Kuching city where the soil was chosen to be treated in this study. The soil sample was mixed with 2 %, 6 % and 8 % of RBI Grade 81 by weight of dry soil and added with water at optimum water content (OWC) to replicate field site conditions. The modified samples were cured in ambient air for 7, 14, and 28 days. Scanning Electron Microscope (SEM) was utilized to analyze surface morphology of the stabilized soil specifically on the formation of bonding between soils and RBI 81 particles. The experimental results show the highest average peak UCS strength achieved was 1071.6 kN/m<sup>2</sup> at 14 day curing period with 8 % of RBI Grade 81 which is higher than the untreated control sample which was 179.946 kN/m<sup>2</sup>, showing increment by almost six folds. Hence the RBI 81 stabilization technique enhances the local soil structure by improving the inter-cluster bonding, reducing pore spaces in the soil and subsequently increasing the soil's strength.

**Keywords:** Soil stabilisation, microstructure, chemical additive.

## 1. Introduction

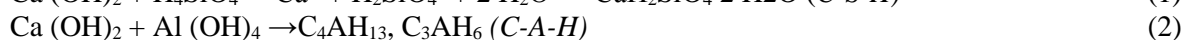
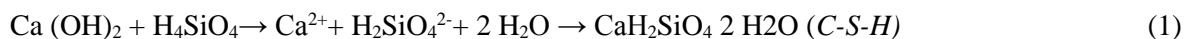
Soft Soils are characteristically known for their low strength, high compressibility and high groundwater table which cause large settlement. Typically due to sedimentary process in various environments, both physical and engineering properties such as void ratio, water content, grain size distribution, compressibility, permeability and strength exhibit substantial variation. In addition, soft soil also exhibit high compressibility (including the important secondary consolidation), reduced strength, low permeability which are unsuitable conditions for construction. Soft clay is also categorized as soft soil and is widely deposited in the state of Sarawak. Due to unavoidable reason such as population and economic growth, development and construction are forced to take place on poor ground such as soft clay. Soft clay has low load bearing capacity and undergo large settlement when loaded. Hence, construction of highways embankment on normally consolidated soft soil deposit has suffered from extravagant settlement and lateral displacement without proper ground improvement before construction implemented [1]. Therefore, ground improvement is needed to avoid these excessive settlements of structures constructed on soft ground.



Stabilisation is an effective technique in improving the engineering properties of soils especially in soft soils. Commonly, soil stabilisation is accomplished via blending and mixing additive with the soil that needs to be improved until the mixture achieves certain improvement in engineering properties [2]. Chemical stabilisation is one type of soil stabilisation that has been widely implemented in field where chemical additives such as cement, lime and fly ash have been used. Chemical stabilisation is very efficacious in strengthening soft and unstable ground in which fundamentally, the chemical additives will alter the mineralogical structure and ameliorate the inherent weak properties of soil for example in terms of its strength and stiffness [3].

Geophysical In this research, RBI Grade 81 (Road Building International Grade 81) was used as the chemical additives to stabilize the Serian soil. Serian soil is chosen as Serian is a newly formed division and is one of the main divisions to connect all the other towns in Sarawak via road. RBI Grade 81 is an odourless beige powder that is produced from a number of naturally occurring compound and has pH of 12.5 in saturated paste [4]. The chemical is insoluble in water, non UV degradable, inert, and chemically stable and work well by hydration reaction [5]. Moreover, it has capability to improve structural properties of wide range of soil especially with silty clay soil with low geo-mechanical qualities [4, 5, 6]. The hydration process takes place and filled the pore space with crystalline growth. In addition, usage of small dosages of RBI Grade 81 can effectively increase the volume stability of the soil [5, 6, 7]. The reaction between RBI Grade 81 and the soil will develop an inter particle matrix that binds the soil particle together into rigid mass. Via both chemical bonds and frictional forces, the binding soil particle serves to limit the pore volume of the created rigid stabilized soil system [5, 6, 7]. RBI Grade 81 form dust free surface, simple to use and harden fast. Benefits of RBI Grade 81 are durable, permanent, aesthetical and environment friendly [5]. Plus, soils treated with RBI Grade 81 exhibit increase of strength with time and even able to obtain strength after one year of application in soil [7]. RBI Grade 81 alters clay irreversibly into cementitious calcium silicate and aluminium hydrate where it also creates volume of stable layer with small capillary spaces [6] and reduces the permeability of soil mass [7].

Stabilisation Typically when the RBI Grade 81 added in the soil, there will be chemical reaction which takes place and is mainly of pozzolanic reaction. During the pozzolanic process, the Calcium Hydroxide released by additives will react with the clay mineral typically aluminous and siliceous which can induce the pozzolanic properties [8]. Hence high concentration of Calcium will produce free  $\text{Ca}^{2+}$  for the chemical reaction with silica and alumina from the clay which leads to the formation of cementitious compounds; calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H) as shown in Eq. (1 & 2) [9].



## 2. Materials and Methods

### 2.1 Soil Sample

The soil sample used for the present study was collected from Serian. The soil is classified as High Plasticity Silt (MH) according to the Unified Soil Classification Systems (USCS). Properties of this Serian soil are summarized in Table 1.

**Table 1.** Properties of Serian soil.

Property	Characteristic
Liquid limit, LL (%)	55
Plastic limit, PL (%)	32.3
Plasticity Index, PI (%)	22.7
Linear Shrinkage, LS (%)	10.4
Maximum Dry Density, MDD ( $\text{Mg/m}^3$ )	1.74
Optimum Water Content (%)	23.5
Specific gravity, $G_s$	2.6
Grain Size Distribution (%)	
Sand	24
Silt	54
Clay	22

### 2.2 Additives

RBI Grade 81 added at 2 %, 4 %, 6 % and 8 % of total dry mass.



**Figure 1.** RBI Grade 81.

### 2.3 Sample Preparation

The collected sample was sun dried until totally desiccated. Next, the untreated samples were sieved passed through the 2 mm sieve. Then, the sieved untreated clay was mixed with RBI Grade 81 (at various percentages of total dry mass) and required amount of water. The water contents were at Optimum Water Content and MDD. The mixture was mixed thoroughly and compacted via a special miniature compacter until it reached required dry density and moisture content. All prepared samples have dimension of 35 mm internal diameter and height of 70 mm. The sample preparation process

needs to be performed quickly to avoid any cementitious bonds in the soil to break due to delayed compaction. Hence in this study, sample preparation was done within 10 minutes to avoid low quality soil mixture. Next, the prepared samples were air cured for 7, 14 and 28 days in temperature and humidity of 25°C and 95% respectively.

### 3. Results and Discussions

#### 3.1 Standard proctor test

The standard proctor test was done based on BS 1377: Part 4: 1990. The values in Table 2 show clearly that the maximum dry density increase with increase in RBI Grade 81 content.

**Table 2.** Summary of MDD and OMC of Soil with 2%, 4%, 6% and 8% of RBI 81.

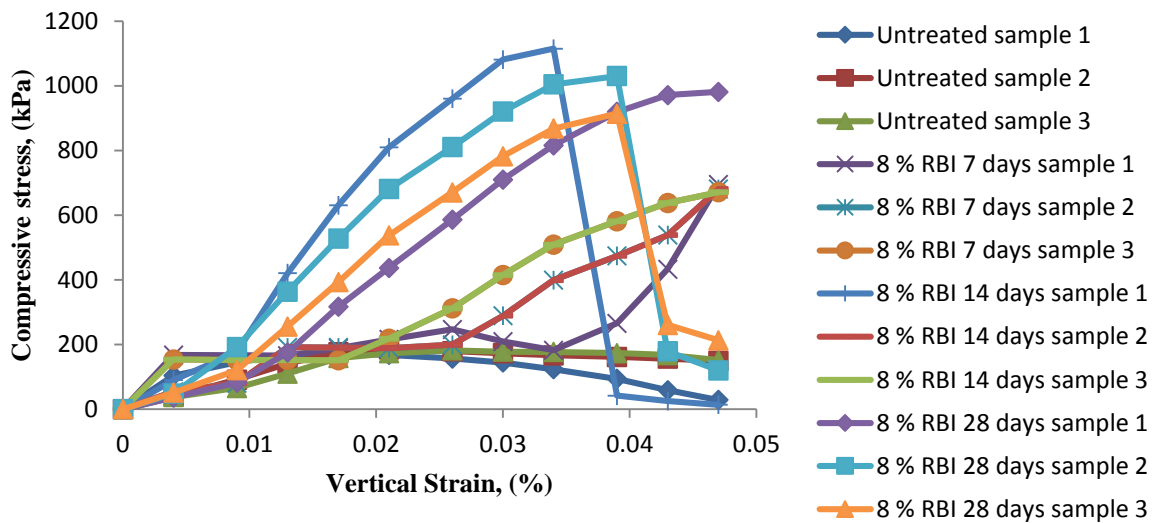
Mix proportion	MDD (Mg/m <sup>3</sup> )	OMC (%)
Untreated	1.74	23.46
Soil + 2% RBI Grade 81	1.81	24.45
Soil + 4% RBI Grade 81	1.82	24.60
Soil + 6% RBI Grade 81	1.84	25.73
Soil + 8% RBI Grade 81	1.90	26.46

#### 3.2 Unconfined compressive strength test

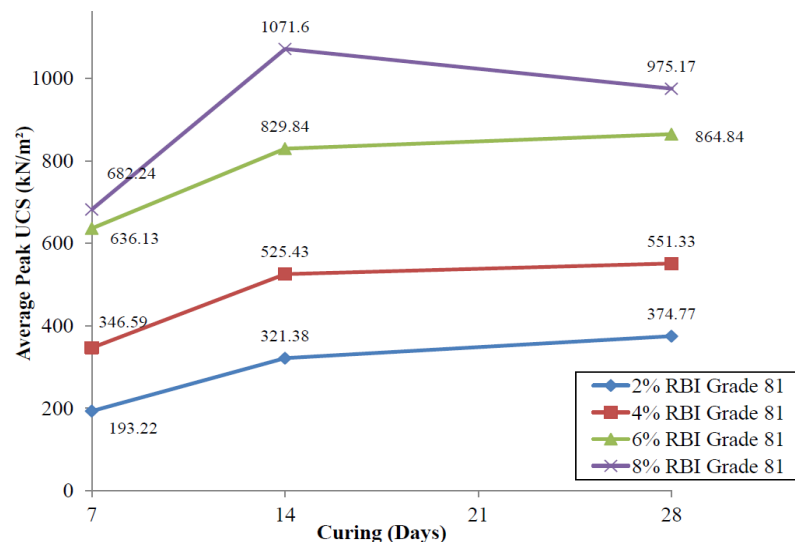
The values of unconfined compressive strength of all the specimens with different amount of RBI Grade 81 added are presented in Figure 2 until Figure 4. As shown, increased amount of RBI Grade 81 induced improvement in term of strength for the specimen tested. Moreover, strength of specimen also improved proportionally to curing time and this tendency becomes more prominent with increase of RBI Grade 81 used. In Figure 2, 8 % of RBI Grade 81 shows the average maximum strength of 1071.6 kN/m<sup>2</sup> and is observed on the 14 day curing, which is more than six time the strength of untreated soil. Minimal reduction of strength occurs on 28 day curing perhaps caused by strength loss due to either shrinkage crack that was developed within stabilized soil or probably due improper curing. Excess of RBI content and insufficient water content to react with the excess RBI may also contribute to the condition.

Figure 3 shows the effect of curing time in increasing the strength of the samples. The graph shows that all samples exhibit strength improvement over time. As seen earlier, 8 % of RBI Grade 81 treated soil achieved maximum strength on the 14 day curing. From Fig 3, in general, it can be concluded that treated samples had greater strength after curing when compared with untreated sample.

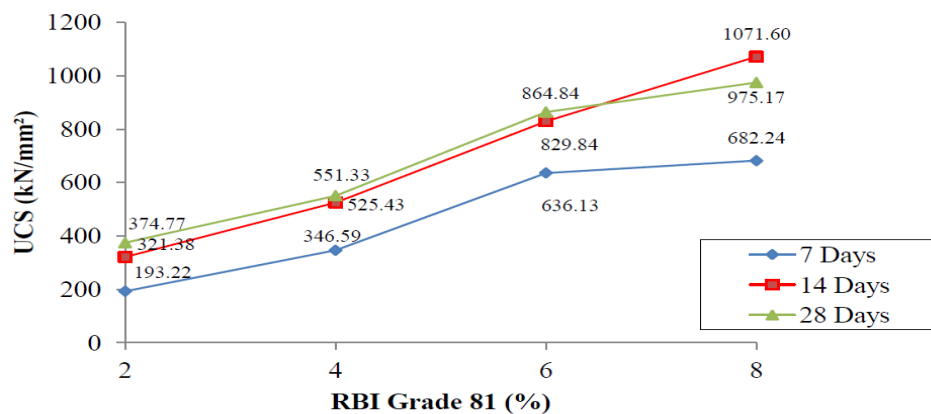
As can be observed in Figure 4, increase of strength can be seen when the amount of RBI Grade 81 is increased in treating the soil. From the figure, 8 % of RBI Grade 81 achieved the greatest strength compared to 2 -6 %. This strength enhancement is shown as more amount of RBI Grade 81 will consist higher amount of free Ca<sup>+</sup> available for the reaction with silica and alumina from the clay which caused the formation of higher cementitious compounds - the calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H).



**Figure 2.** Graph of Untreated Soil and 8 % RBI Grade 81 treated soil.



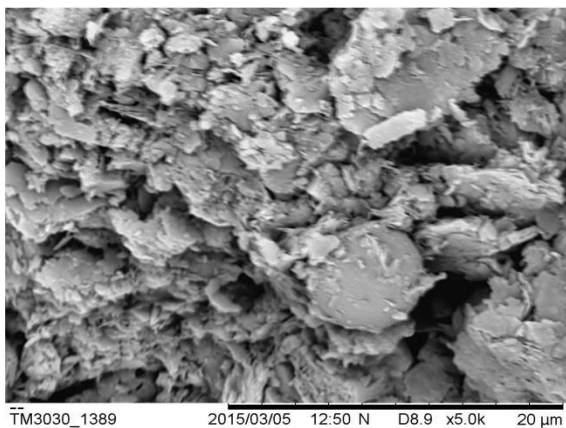
**Figure 3.** Effect of curing time on RBI Grade 81 treated soil.



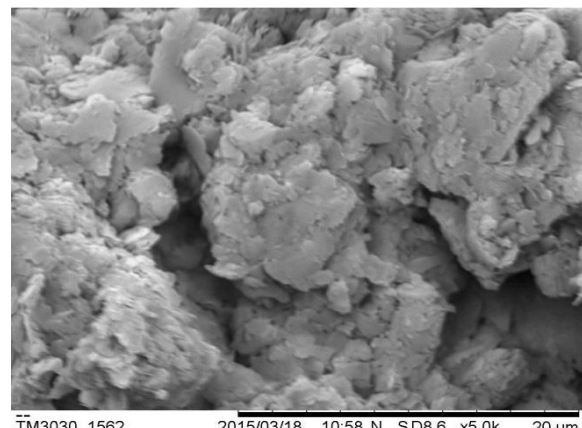
**Figure 4.** Effect of content on RBI Grade 81 treated soil .

### 3.3 Microstructural analysis

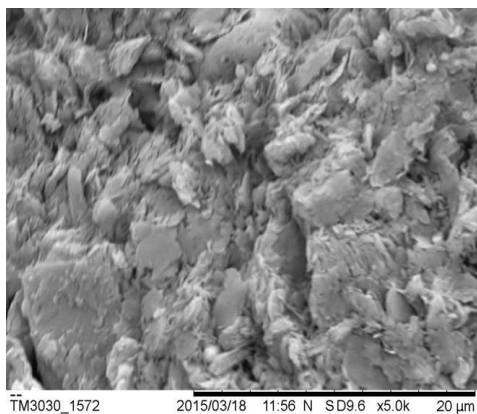
Model TM3030 Hitachi Tabletop Analytical Scanning Electron Microscope (SEM) had been used to investigate the microstructure of the natural soil and the RBI Grade 81 treated Serian soil. Figure 5 and 6 show the microstructure of natural soil under 5000 $\times$  magnification and 2 % RBI Grade 81 7 day curing treated soil under 5000 $\times$  magnification respectively. Figure 7 and 8 present the microstructure of 6 % RBI Grade 81 stabilised soil cured for 7 day and 28 day at 5000 $\times$  magnification respectively. Fig 5 is the untreated soil which has many empty pores as indicated from the darker contrast area. When compared to Figure 6, most of the pores were filled with the cementitious products due to the chemical reaction within. However, Figure 7 shows more of cementitious products compared to Figure 6 due to the effect of higher amount of RBI Grade 81. The adsorption of higher amount of  $\text{Ca}^{2+}$  ions in the 6% sample onto the clay particle surface decreases the repulsion between successive diffused double layers and increases edge-to-face contacts between successive clay sheets [10] and the clay particle flocculate into larger particle [11,12]. The cementitious products improve the inter cluster bonding strength and filled the pore space significantly which directly reduce the total pore volume, also induced increment of compressive strength. The effect of curing was observed in Figure 7 and Figure 8. Figure 8 shows more densification of the morphological surface compared to Figure 7 due to growth of cementitious product over time.



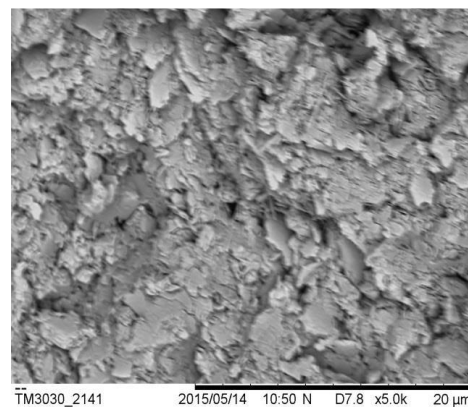
**Figure 5.** Untreated Natural Soil.



**Figure 6.** 2 % RBI 81 treated soil (7 days Curing)



**Figure 7.** 6 % RBI 81 treated soil (7 days Curing).



**Figure 8.** 6 % RBI 81 treated soil (28 days curing)

## 4. Conclusion

This research was intended to study the effect of RBI Grade 81 as additive to stabilise the Serian soil. Samples were prepared at Optimum Water Content (OWC) and Maximum Dry Density (MDD) to

replicate field site conditions. All samples were air cured for 7, 14 and 28 days. Results showed that the RBI 81 stabilised soils show increased in soil strength under various curing periods. The experimental results show the highest average peak UCS strength achieved was 1071.6 kN/m<sup>2</sup> on 14 days curing period at 8 % of RBI Grade 81 which is higher than the untreated control sample which was 179.946 kN/m<sup>2</sup>, increment by almost six folds. Longer curing period should allow further enhancement in strength. Unconfined Compressive Strength (UCS) values increase with increment in RBI 81 addition suggests its suitability as good additive to improve performance of soft soils. SEM also provides reliable evidence on the effect of calcium hydroxide from RBI Grade 81 to the soil matrix via its morphological images. The presence of cementitious products in the microstructure of the RBI 81 stabilised soil supported the result of UCS test. Formation of the cementitious products had increased the shear strength of the RBI 81 stabilized Serian soil.

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