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Comparison between Hydrated Lime Dry Powder and Slurry on Peat Soil Stabilization

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ABSTRACT

This study investigates the effect of soil stabilization using hydrated lime on peat soil. Hydrated lime admixtures were prepared in two different methods; namely: lime powder (dry) and lime slurry. The stabilization of soil samples were performed under three different proportions which are 3%, 6% and 9% of weight of dry peat soils. Compressive strength of stabilized peat soil under different mixtures process were evaluated by unconfined compressive stress test (UCT), and the performance of this admixture will be compared. Three different curing times are considered, namely; immediate, 3 days and 7 days curing period. Lime slurry method for peat soil stabilization is more effective compared to lime powder admixture. Results obtained from the tests shown that the Unconfined Compressive Strength values under lime slurry were increased with the increasing lime percentage and longer curing time period. The maximum improvement was 950 % under lime slurry and for 7 days curing period compared to the untreated peat soils. However the unconfined compressive strength for lime powder decreases around 60% to 63% with the increment of curing period.

Keywords: *Peat soil, Lime stabilization & Unconfined Compressive strength*

Introduction

Geotechnical engineering community have recognized that problematic soils may result in considerable distress and consequently in severe damage to overlying structures. Major of geotechnical problems involving soft soils are due to their low strength, durability and high compressibility. Alternative areas for construction became however more and more important during the last decades due to growing shortage of better quality soils for construction.

Peat is a common land surface material in many countries of the world and is particularly important in Malaysia. Further, characteristic of peat are very important in evaluating is as a plant growth medium. Peat is a biogenic deposit which when saturated consists of 90-95% water and about 5-10% solid material. The organic content of the solid fraction is very high, often up to 95% and is made up of the partly decayed remains of vegetations which have accumulated in waterlogged (*Huat, B.B.K., 2004)*. Peat deposits occur in areas where water logging is common. Peat soil represents the extreme form of soft soil. They are subjected to instability such as localized sinking and long-term settlement when subjected to even moderate load increase (*Huat B.B.K, et. al., 2005*). Building on peat is usually suspended on piles, but the ground around it may still settle, creating a scenario as shown in Figure 1 and Figure 2.

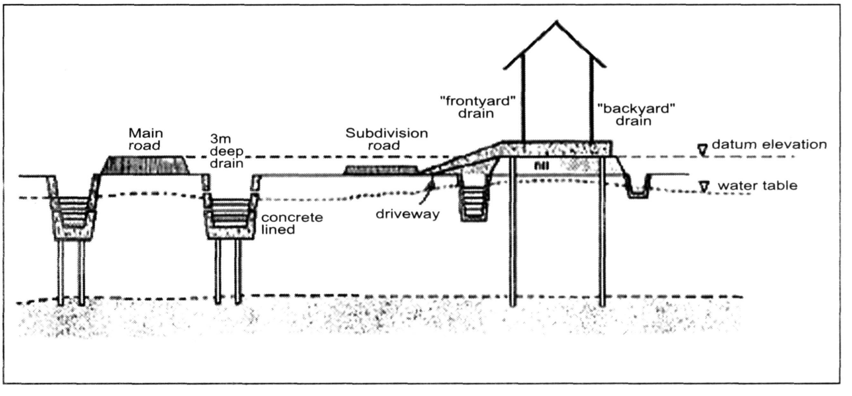

Figure 1: Immediate After Completion. (*Huat B.B.K, et al., 2005*)

Figure 1 illustrated the building that construct on peat soil. The effect of building on peat soil does not occur just the construction had finished. After several years, the buildings are starting settled down. This is because the peat soils are continuous to settle. The effects are show on Figure 2. From Figure 2, the usual effect is creaked driveway, broken drain, tilted house and road settled.

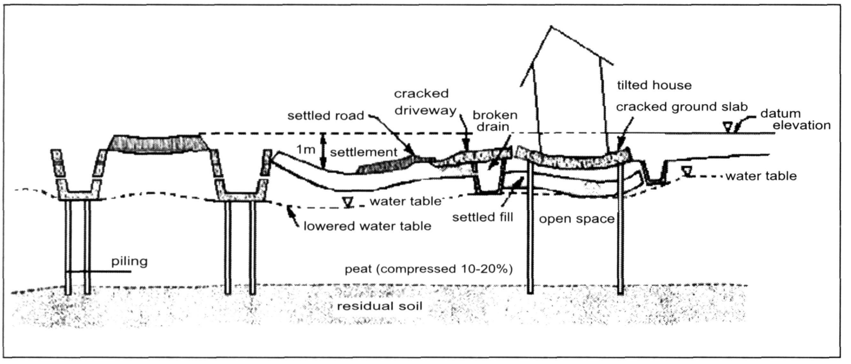

Figure 2: Several Years After Completion of Construction.
(*Huat B.B.K, et al., 2005*)

Peat Soil Properties

Tropical peat or tropical peat lands of the total world coverage is about 30 million hectares, two third of which are in Southeast Asia. Malaysia has some 3 million hectares (about 8%) of the country land area covered with tropical peat. In Indonesia, peat covers about 26 million hectares of the country land area, with almost half of the peat land total is found in Indonesia's Kalimantan (*Huat et al., 2005*). Since the coverage of these soils is quite extensive, utilization of these marginal soil are required in increasing number of development projects in the recent years. Hence suitable geotechnical design parameters and construction techniques needed to be found for this type of ground condition. It is therefore necessary to expand our knowledge on the engineering or mechanical properties of the peat and organic soils.

The stiffness values of the surface and underlying weak peat deposits from load-shrinkage test were determine by specially made bearing capacity apparatus. The mean value of surface stiffness before and after drainage was found to be 31 and 45.62 kN/m^3 respectively (*Desa, 2004*). The mean value of internal frictional angle, cohesiveness and shear deformation modulus of peat soil sample were determined by using direct shear box apparatus. The mean value of internal friction angle, cohesiveness and shear deformation modulus before and after drainage were found to be 22.8° and 24.13°, 2.89 kN/m^2 and 1.21 cm respectively (*Desa, 2004*).

The few measurements reported on bulk density values ranging from 0.05 g/cm^3 in fibric, for very undecomposed materials, to less than 0.5 g/

cm^3 in well decomposed sapric material. The higher bulk density values of 7% to 8% of a mineral soil imply high pore space in organic soil. Most soils shrink when dried but swell when re-wetted over drainage can cause irreversible drying and shrinkage. The lost of water and colloidal changes lead towards considerable and irreversible shrinkage of some organic soil, which would then deteriorate to a granular powder with unattractive physical and agricultural properties (*Tie and Kueh, 2002*).

The bearing capacity of organic soil varies considerably with moisture content and generally improves with decreasing moisture content (*Rogers, et al., 1996*). Therefore, the bearing capacity is indirectly linked to the water table level in soil. Hydraulic conductivity in peat soil are controlled by several factors the most important being the porosity. Other factors are the degree of decomposition and bulk density which are both indirectly related to the porosity. Course fabrics materials have a low bulk density as well as large pores. Soil acidity (pH) of organic soils was found to be highly correlated to the decompositions rate, the higher the pH, and the greater the decomposition rate. The ranging of pH value was found 3.2 to 4.0. (*Huat B.B.K., 2004*).

Hydrated Lime

Lime has two reactions, namely: lime modification and lime stabilization. Lime modification where an immediate improvement in workability, placeability and compatibility of the soil is achieved where lime stabilization are where an additional long term improvement in the strength and resistance to adverse weather condition is obtained

Lime is an effective additive for plastic soil, improving both workability and strength. It is not effectives in cohesion less or low cohesion materials without the addition of pozzolanic additives. There are many similarities between materials stabilized with cementitious stabilizing agents and lime. They have similar composition, resulting Incomparable behavior, and require similar materials characterization, structural design procedures and construction considerations.

The addition of lime to these soils has the potential to increase strength and reduce volumetric deformations. This research tries to elucidate questions about the efficiency of existing methodologies in determining the minimum lime amount needed for organic soil stabilization, the effect of the amount of lime and curing time in the stiffness and strength of treated material under un-drained conditions, as well as in the effective

Table 1: Physical Properties of Peat soil from Previous Researches

Sources	Bujang BK Huat	Simon Rabaujedy	Abdul Malek Bouazza	Rayya Hassan	Fuad Sukkar	K. Mc Manus	Jarret P.M.	Faisal Hj Ali	Simon Rabarijoey
Water content %	605-1290	310-340	603	334	200-300	20-160	370-540	223-690	310-340
Liquid limit %	>120	305-310	350-450	321	>120	40-125	>150	216-324	305-310
Plastic Limit %	>100	128	200-250	128	> 100	20-40	>120	138-255	164
Specific Gravity	1.2	1.841	1.53	1.841	N A	N A	1.41 - 1.7	1.5-2.0	1.45
Organic content %	>75	65-75	46	50	70-80	40-70	84 - 95	17-80	65-75
Unit weight (KN/m)	1.02-1.43	1.6	1.6	0.87-1.04	1.02-1.43	N A	1.5-1.6	9.6-11.5	N A
pH	3.0-4.5	3.2	5.4	4.3	N A	N A	N A	N A	N A
Undrained Shear Strength (kPa)	10	15	17	10	N A	N A	N A	17	19
Plasticity Index %	>20	180	175	193	>20	52.5	25	88.5	143.5

strength parameters (*Rogers, et al., 1996*). Organic of soft soil are quite problematic soils due to their low strength and high deformability. The addition of lime to this soil has the potential to increase strength and reduce volumetric deformations.

Experimentals

Soils classification tests were performed based on British Standards 1377:1990. Sieving-sedimentation analysis with wet sieving and followed up with a determination of fine particles by the hydrometer procedure as explained by Head (1992). The parameters that are related with basic physical and engineering characteristic of fine soil which is specific gravity, Atterberg limit, optimum moisture content, particles size distribution, permeability and shear strength were obtained from the laboratory test. Results of soil physical properties and classification are summarized as in Table 2 below:

Table 2: Soil Properties Parameter

Soil Property	Properties Parameter
Specific Gravity, (Mg/m^3)	1.76
Plastic Limit, (%)	20
Liquid Limit, (%)	50
Plasticity Index, (%)	30
Optimum Moisture Content, (%)	20.8
Maximum Dry Density, (Mg/m^3)	1.63
Moisture content, (%)	43.98
Unified Soil Classification System.	MI
Unconfined Compressive Test.	

Materials

Peat soils sample were collected at 0.5 m depth after removing the top soil. Peat soil as shown on plate 1 was obtained at Bertam Palm Estate, Pulau Pinang. The samples were represents peat with organic content in range of 75% to 94%, natural water content 40% and 50%. These soils have typically low specific gravity in the range of 1.74 Mg/m^3 to 1.80 Mg/m^3. According to Van Post scale (*Landva et al., 1983*), these soils are classified in the H7 group, namely hemic to sapric peat.

From the physical properties test, the type of fine soil is organic silts of intermediate plasticity. Besides the value of liquid limit and plasticity

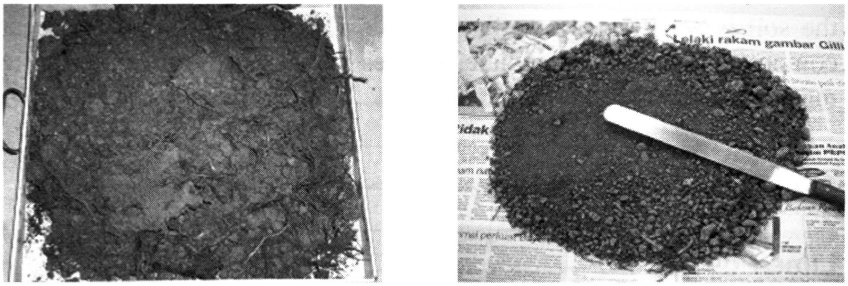

Plate 1: Peat Soils Samples

index are 50% and 30% respectively, so the soil classification is MI (silt of intermediate plasticity) as according to Unified Soil Classification System (USCS) chart.

Unconfined Compressive Text

In general, lime contents instituted, ranging from 3% to 6%, have contributed to a significant increase in unconfined compressive strength, from 2.5 to 11 times of the untreated soil (Kassim & Kok, 2004). In this research, three different proportion of hydrated lime were selected. There are 3%, 6% and 9%. Besides, the performances of the hydrated lime stabilization on peat soil under different curing period were investigated to observe the pattern of their improvement. The admixtures of hydrated lime and peat soils were prepared as follow:

Lime Powder (test by UCT)

a. 3% weight of lime powder mixes with 3 kg of dry weight of peat soil.
b. 6% weight of lime powder mixes with 3 kg of dry weight of peat soil.
c. 9% weight of lime powder mixes with 3 kg of dry weight of peat soil.

Lime Slurry (test by UCT)

a. 3% weight of lime slurry mixes with 3 kg of dry weight of peat soil.
b. 6% weight of lime slurry mixes with 3 kg of dry weight of peat soil.
c. 9% weight of lime slurry mixes with 3 kg of dry weight of peat soil.

Curing Period

Three different curing times which are **immediate, 1 day and 7 days** were used to investigate the curing effect. Lime modification where an immediate improvement in workability, placeability and compatibility of the soil is achieved. Immediate reaction between the lime and peat composite produced immediate changes in soil plasticity and bringing many benefits.

Result and Discussion

Lime Powder

Compressive strength of soil samples treated with lime powder increased proportionate with the increment of lime contents. Table 3 and Figure 3 show the performance of peat soil treated with hydrated lime powder. The highest increment was 443 % for immediate curing effect. However, the strength of treated samples decreased with the longer curing period. For instance, 9% lime content compressive strength reduced around 63 percent, from 613.7 kN/m² to 229.7 kN/m² for immediate and 7 days curing period respectively. The samples treated with hydrated lime powder didn't give consistent reading. The samples cured for a longer time period become brittle and the samples tested were easily fails. The results are shown in the Table 3.

From Figure 4, the compressive stress is decrease for long time period. This is because the reaction of lime soil will combined to form larger particle. This is made the sample become brittle.

Lime Slurry

Soil sample that test under lime slurry preparation are give more consistent reading under unconfined compressive stress. The compressive stress is increase proportionally with increasing of lime and long time period.

Table 3: Compressive Stress Sample under Different Percentage of Lime Powder

Curing	Average Compressive for untreated sample (kN/m²)	Treated with 3% of lime (kN/m²)	Treated with 6% of lime (kN/m²)	Treated with 9% of lime (kN/m²)
Immediate	113	334.3	455	613.7
3-Days curing	108	205	267	373.33
7-Days curing	104	147.7	166.3	229.7

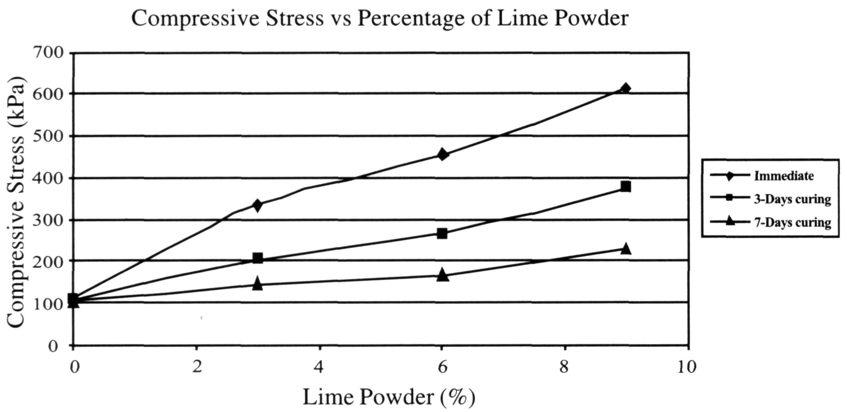

Figure 3: Compressive Stress versus Lime Percentage for Lime Powder

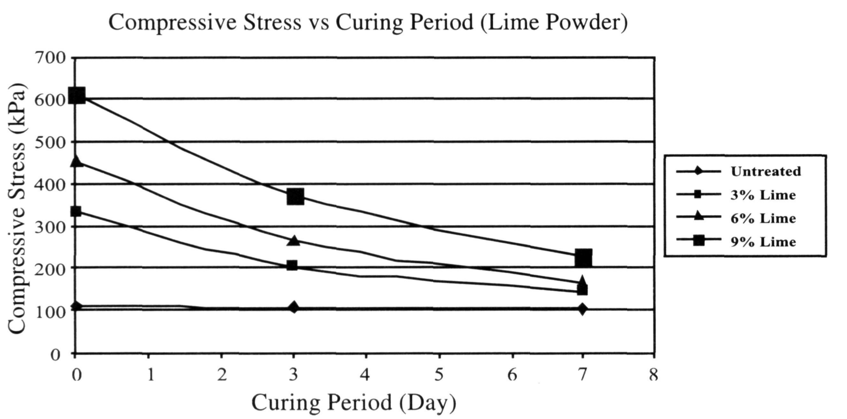

Figure 4: Compressive Stress versus Time Curing Period for Lime Powder

From Table 4 and Figure 5, the compressive stress of samples under lime slurry preparation method were increased proportionate with the increment of lime percentage and for longer time period. The compressive stress for 9% of lime at immediate curing was 664.3 kN/m^2 while after 7 days curing period the compressive stress was increased to 1092.3 kN/m^2.

From Figure 6 the compressive stress are increase proportionally with the increasing in curing time period. The highest increment was 64% for 9% of hydrated lime slurry under 7 days curing period. The performance of treated samples (9%) compared to the untreated samples for 7 days curing period were 104kN/m^2 and 1092.3 kN/m^2 respectively.

Table 4: Compressive Stress Sample under Different Percentage of Lime Slurry

Curing	Average Compressive for untreated sample (kN/m²)	Treated with 3% of lime (kN/m²)	Treated with 6% of lime (kN/m²)	Treated with 9% of lime (kN/m²)
Immediate	113	140	515.7	664.3
3-Days curing	108	234.3	594.33	752.33
7-Days curing	104	308	660	1092.3

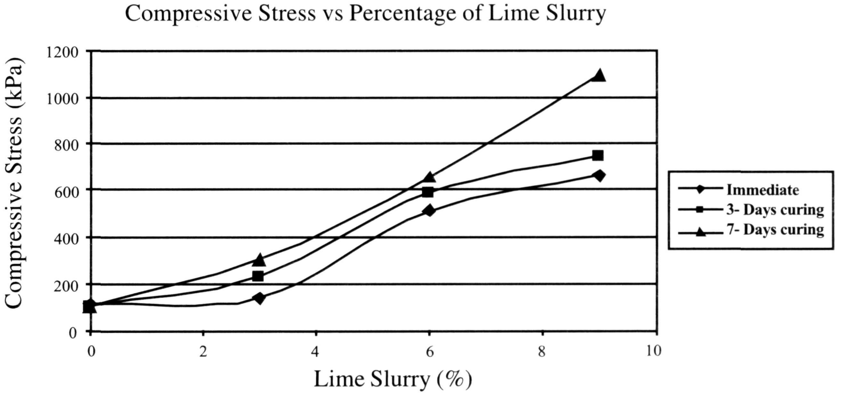

Figure 5: Compressive Stress versus Lime Percentage for Lime Slurry

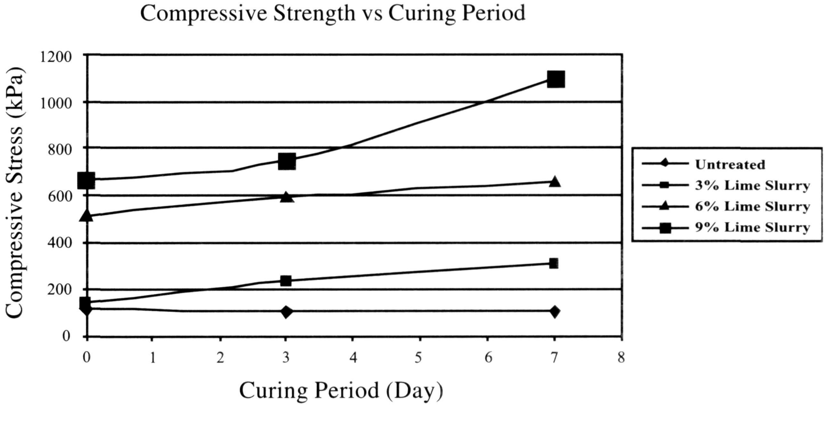

Figure 6: Compressive Stress versus Curing Period for Lime Slurry

Table 5: Compressive Stress between Lime Slurry and Lime Powder

Lime % / Curing time	Average Compressive for 3% of lime (kN/m²)		Average Compressive for 6% of lime (kN/m²)		Average Compressive for 9% of lime (kN/m²)		Average Compressive for untreated sample (kN/m²)
Lime Preparation	*Lime Slurry*	*Lime Powder*	*Lime Slurry*	*Lime Powder*	*Lime Slurry*	*Lime Powder*	
Immediate curing	140	334.3	515.7	455	664.3	613.7	113
3 days curing	234.3	205	594.33	267	752.33	373.33	108
7 days curing	308	147.7	660	166.3	1092.3	229.7	104

The average unconfined compressive strength improvement was almost 950%.

Results in Table 5 shows that unconfined compressive stress under the lime slurry was higher compared to the lime powder. The extreme comparison between two methods was at 9% lime and 7 days curing period, where the different of unconfined compressive strength obtained between lime slurry and lime powder was 348%. This shows that, peat soil treated with lime slurry perform better compared to the stabilization of peat soil using lime powder.

From Figure 7 the compressive for lime slurry is greater than lime powder except for immediate curing time, compressive stress for lime powder is greater than lime slurry. It is also shown that the compressive strength for lime powder decreased for longer time period while for lime slurry the compressive increased for long time period.

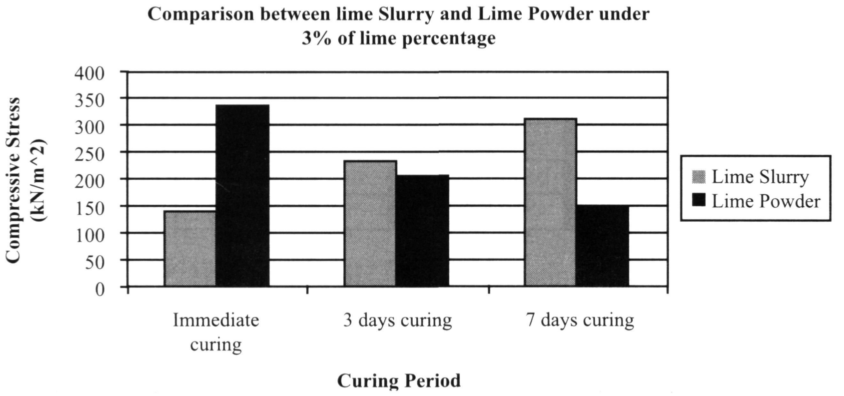

Figure 7: Comparison Compressive Stress between Lime Powder and Lime Powder Slurry for 3% of Lime Percentage

From Figure 8 the compressive stress for lime slurry is greater than lime powder, .It is also show the compressive for lime powder are decrease for long time period while for lime slurry the compressive are increase for long time period.

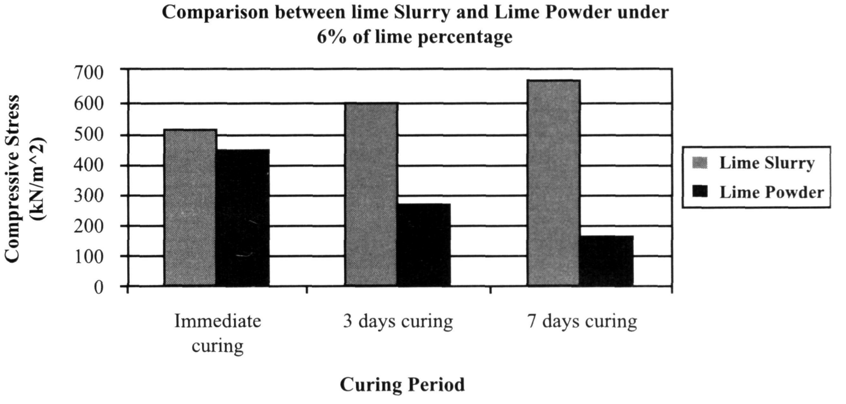

Figure 8: Comparison Compressive Stress between Lime Powder and Lime Powder Slurry for 6% of Lime Percentage

From Figure 9 the compressive stress for lime slurry is greater than lime powder, .It is also show the compressive stress for lime powder are decrease for long time period while for lime slurry the compressive are increase for long time period.

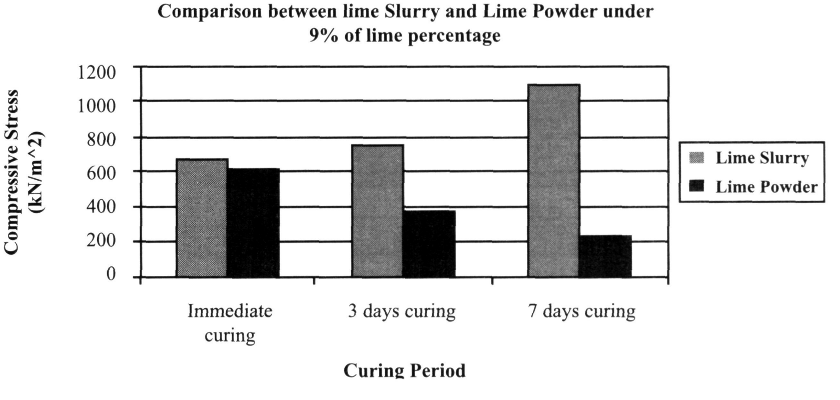

Figure 9: Comparison Compressive Stress between Lime Powder and Lime Powder Slurry for 9% of Lime Percentage

Conclusion

The unconfined compressive strength for peat soil stabilization using hydrated lime shows the increment proportionate to the increment of lime content, regardless for lime powder or slurry. The highest improvement of treated peat soils was under lime slurry method, where the increment of compressive strength was 950 % compared to the untreated samples under the same curing period. The improvement for the same condition for lime powder was 121%.

However, the performance of treated soils for lime slurry and lime powder under curing period was totally different. The unconfined compressive strength of treated samples under lime slurry improved significantly while, the performance of lime powder method decreased. The stabilized samples under lime powder method becomes brittle and easily broken after curing period and this lead towards the decreasing of unconfined compressive strength of samples. The strength loss under lime powder mixed method for immediate to 7 days was around 60 to 63%. This phenomenon is occurred due to the ineffective of lime modification process during the early stage of lime stabilization.

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