IMPROVEMENT OF ENGINEERING PROPERTIES OF PEAT BY CEMENT AND LIME MIXING

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ABSTRACT

Development of cost effective methods for improvement of engineering properties of peat is a need of the hour in Sri Lanka in view of the number of major infrastructure development projects that are proposed over the lands underlain by peat. Pre consolidation by preloading was the method adopted in Sri Lanka to date except for the use of dynamic consolidation in one site. The main drawback in the preloading technique is the long time period required. As such, in the research reported in this paper an attempt was made to study the improvements that can be achieved in engineering properties of Peat by mixing with cement or lime.

The level of improvement achievable is expected to depend on the level of humification of the Peat and its organic content. Hence, Peats at different levels of humification were used in the study. Peats were mixed in the laboratory with Cement at percentages of 5, 10 and 15 and with lime at 15 % on the wet weight and left to harden for a periods of 2 and 4 weeks.

The results of the subsequent tests revealed that even the mixing of 5 % of cement caused significant improvements in an Amorphous peat. A higher percentage 15 % of lime was required to bring about improvements of the same order in the amorphous peat. Even after the mixing of 15% of cement or 15% of lime appreciable improvements of consolidation characteristics were not seen in fibrous peat. Improvements of shear strength were achieved in all types of peat with preconsolidation and with both cement/lime mixing.

BACKGROUND

With the developments taking place in the country, there is a scarcity of lands with good sub soil conditions in and around Colombo and other major cities. Therefore, Civil Engineers are compelled to build new structures and infrastructure facilities in areas where existing ground conditions are not very favourable. In the city of Colombo and suburbs, number of new projects are proposed at locations where there are soft organic clay/peat layers of thickness as high as 10m. Construction on soft Peats leads to stability problems during the construction and long-term settlements during the service due to its very low shear strength and very high compressibility.

Although the heavy loads from the super structure of a multistory building can be transferred to an underlying harder stratum through piled foundations, it is not the most economical form of foundations when the roads, service lines and lightly loaded buildings are to be constructed. In such situations the use of shallow foundations after the improvement of the peat layer will be a more economical option.

Different methods are available for the improvement of compressibility and shear strength characteristics of soft clays and peat. These methods can be classified primarily as densification processes and solidification processes. Preloading, vacuum preconsolidation and dynamic compaction are some of the
most widely used densification techniques. In the preloading technique the subsoil is preconsolidated by applying a load (with a soil fill) that is equal to or greater than the intended structural load. Once the required consolidation is achieved the preload fill shall be removed and the final structure is constructed. The main criticism against the preloading is the rather long time period required for the process. Although the time period can be reduced by the use of vertical drains the staged construction required in very soft Peat may extend the period of treatment. As such, development of more rapid and cost effective methods is a need of the hour.

Deep mixing method is a solidification technique where the existing soil is mixed with cementitious material using mixing shafts. The soil-cement composite produced is of extremely high strength and lower compressibility. This method is successfully applied for soft inorganic clays by Japanese and Swedish geotechnical engineers over the last two decades. Addition of lime or cement has proved to be a very effective and reliable way of achieving a rapid improvement of engineering properties of the soft inorganic clays.

There are some limited information available about the use of this technique for organic clay and Peat from Sweden and Finland. Several research projects have commenced within last five years. There were laboratory studies as well as instrumented field applications. In Sri Lankan peats, organic content varies usually between 20% and 30%. This value is very low compared to values reported in geotechnical literature. In Russia the term peat is used when the organic content is more than 50% and in USA the term peat is used when the organic content is more than 75%. (Hobbs 1987). On that basis the peats that we encounter in Sri Lanka can be classified as peaty clays. Considering this rather low organic contents, the Cement and Lime mixing has the potential to be a very effective and reliable way of achieving a rapid improvement of engineering properties of the peat.

The behaviour of a peat or peaty clay will depend on the degree of humification. As such, peats at different levels of humification; a fibrous peat at a very low level of humification and an amorphous granular peat at a high level of humification were used in the study. Both types of peat exist in Sri Lanka and the level of humification can vary within a short distance even in the same locality. The paper compares the improvements achieved by cement and lime mixing with the improvements achieved by preloading, for the two different type of peat.

DEEP MIXING METHOD IN THE FIELD AND MECHANISM OF IMPROVEMENT

In the deep mixing technique, the existing soft clay or peat layer is mixed with the cementitious material or hardening agent using mixing shafts, auger cutting heads and mixing paddles. Cementitious materials are generally delivered in grout or slurry form from parts in the cutting head located in the lower end of the multiple shafts. The techniques were developed independently by Japanese and Swedish geotechnical engineers over the last
three decades. At the initial stages the mixing was achieved through either mechanically by paddles or by high pressure. Now there are machines which uses a combination of the two processes and hence produce much larger diameter treated columns more efficiently. Different names such as DLM(Deep lime mixing), CDM(Cement Deep Mixing) etc were used for the process depending on the hardening agent used. Porbaha (1998) provides a comprehensive state of the art report on the deep mixing method.

Cement and lime were used as the hardening agents in the deep mixing technique for a long time. A combined mix of cement and lime came into the use much later. In recent times various forms of binder which are a mix of cement or lime with various industrial by products were tried out by Swedish and Finish geotechnical engineers for the improvement of organic clays and Peat. (Lahtinen et al (2000), Jelistic and Leppanen (2000), Rogbeck et al (2000), Huttunen et al (1996)). Industrial by products such as blast furnace slag and Finnstabi a Gypsum based by product were used in these studies. Some of them have seen to be much more efficient than Cement or lime. The binders based on these industrial by products are less expensive also. The choice of the most appropriate hardening agent is a major decision and it is best to do that after sufficient laboratory tests and some field trials. Rogbeck et al (2000) discussed about the use of CM binder – (a mix of 50% S H Cement and 50 % blast furnace slag) with organic soil. Effectiveness of this was compared with the cement/lime mix. The laboratory investigations have shown the CM-binder to be superior than cement/lime, but much difference was not indicated in the field studies. This again highlights the importance of verifying the laboratory results in the field.

No theoretical explanations were available yet on the effectiveness of the various forms of binders with organic clays and Peats of very different initial water contents and levels of humification but the The mechanism of improvement with cement and lime mixing is reasonably well understood. In the mixing with lime either quick lime (CaO) or slack lime (Ca(OH)2) will be used. Quick lime absorbs water in the soil and becomes slack lime. The Ca 2+ ions in slack lime reacts with soluble constituents in the soil, SiO2 and Al2O3 and a secondary reaction called the pozzolanic reaction takes place. The hydrated product produced called Ettringite [3 CaO.Al2O3.CaSO4.3H2O] is a needle shaped crystal with a cross linked structure and it binds the soil particles together. It also has used up lot of water.

Ordinary Portland cement is made by adding Gypsum to cement clinker formed of minerals C3S, C2S, C3A and C4AF [C:CaO, S:SiO2, A:Al2O3, F:Fe2O3, H: H2O] and grinding it into a powder. The minerals will react with water in the soil to form large molecules 3 CaO.SiO2.3H2O and together with the formation of the product of cement hydration, Calcium hydroxide is released. The cement hydration product has high strength which increases with age and the calcium hydroxide contributes to the pozzolanic reaction.

When the hardening agent content is increased, it will be able to form more crystal structures binding the soil particles together and the level of improvement will increase. Chang(1999) found that the strength increase goes
on for a much longer period when the added cement percentage was increased. With the greater percentage of cement present the hydration of cement and bonding appear to go on for a longer time. It was also observed through laboratory studies (Chang(1999)) that for a given cement content the strength achieved decreased with the increasing water content. However, there will not be any in the field applications where the mixing had to be done at the natural water content.

LABORATORY SIMULATION OF THE DEEP MIXING METHOD

Field deep mixing process was simulated in the laboratory through mixing of the peat with the added cement or lime in a container using an electric hand mixer. The same speed and time of mixing was maintained to ensure uniformity. Peats were generally of very high water content and the field mixing had to be done under the natural water content. Therefore, the laboratory mixing was also done under the natural water content of the respective Peats. These water contents were much greater than their liquid limits.

In the field operations the mixed soil hardens and chemical changes are taking place under water logged conditions. This condition was simulated in the laboratory by placing the mixed soil in buckets and allowing it to harden under water. The specimen for respective tests were taken after the appropriate hardening periods of 2 weeks and 4 weeks. Both amorphous and fibrous peats were used in the study and cement percentages of 5%, 10% and 15% of the wet weight of the Peat were used. Mixing of a lower percentage of lime did not show up any visible improvement and lime was mixed at 15%.

LABORATORY TEST PROCEDURE AND ENGINEERING PARAMETERS TO QUANTIFY THE IMPROVEMENTS

Peats obtained from three locations were used in the study. They were named after their respective location. Wattala Peat and Peliyagoda Peat are of amorphous type and Madiwela peat is of fibrous type. The level of humification varies considerably within a short distance and other types of peat could be found from these locations. Their basic engineering properties are presented in Table 1.

Improvement of the Consolidation Characteristics

It is necessary to improve the stiffness characteristics of the peat to minimize the settlements associated with the construction and strengths are to be improved to prevent shear failures. As the peat possess very high primary and secondary consolidation settlements the improvement of both types of settlement would be necessary and this was assessed through the parameters compression index $C_v$, the coefficient of volume compressibility $m_v$, and the coefficient of secondary consolidation $C_s$. The fist two are alternate parameters indicating primary consolidation.
These parameters were evaluated using the results of the conventional Oedometer tests. Test were performed on untreated peat and undisturbed samples obtained from cement or lime mixed peat hardened in the buckets. Having considered the dominant secondary consolidation characteristics of peat it was decided to adopt two week long time increments instead of the one day long time increments in the conventional test. Tests were conducted with loading / unloading and reloading increments. The applied loading was doubled after the two week period in both loading and reloading increments.

It was necessary to compare the improvements achieved with deep mixing with cement / lime with the improvements achieved in the more conventional improvement method of preloading. The reloading increments in the consolidation tests served this purpose. The loading increments in the tests done on untreated peat will correspond with the conditions of the natural peat. The reloading increments of the same test corresponds with the behaviour of a preloaded peat. The comparison of properties at the similar stress levels in the loading and reloading increments will indicate the level of improvement achieved with preloading. The parameter m, will indicate the improvement achieved in primary consolidation characteristics and the parameter C_n will indicate the improvements achieved in the secondary consolidation characteristics. Alternatively, the gradient of the e vs log σ plot done with loading increment will provide the compression index C_e and the gradient of the e vs log σ plot done with reloading increments will yield the recompression index C_r. The coefficients C_e and C_r can also be used to assess the improvement of primary consolidation characteristics due to preloading. The compression ratio - C_e / (1+C_n) was also used in the comparisons. Kulathilaka (1999) presented the improvements achieved in the primary and secondary consolidation characteristics due to preloading of Sri Lankan Peaty soils.

The comparison of data from loading increments of cement/lime treated peat and loading increments of untreated peat will indicate the effectiveness of cement/lime mixing. The data from reloading increments of untreated peat and loading increments of cement/lime treated peat can be used to compare the relative effectiveness of the two techniques.

Also, the reloading increments of cement/lime treated peat will indicate the potential improvements achievable by the combined usage of the two techniques. Lahtinen et al (2000) reported about the further strength improvements achieved by the preloading of a cement mixed peat.

**Improvement of the Shear Strength Characteristics**

Under the loading conditions the short term undrained behaviour is more critical. Therefore unconsolidated undrained triaxial tests were conducted to evaluate the shear strength of Peats. Undrained cohesion C_u was used as the main parameter. Although unconfined compression tests were performed by some researchers (Chang (1999), Jelisic and Leppanen (2000)) in this context author was not prepared to do that due to many limitations and drawbacks in the test. Triaxial tests are more reliable and simulates the actual field situation.
Undisturbed specimen were taken from the treated peat after the appropriate hardening period and testing were conducted. In addition, undisturbed sample of untreated peat were also subjected to unconsolidated undrained triaxial tests. The effect of preloading on shear strength was evaluated by conducting consolidated undrained tests on undisturbed Peat specimen. Peat samples were consolidated isotropically at different cell pressures and the deviator load was applied under undrained conditions. The increase of undrained strength due to the increase of consolidation pressure was determined and the ratio $\Delta C_u / \Delta \sigma_3$ was obtained. Although isotropic consolidation may not occur in the field under the preload this was the closest possible simulation with the available facilities.

**COMPARISON OF IMPROVEMENTS ACHIEVED IN PRIMARY CONSOLIDATION CHARACTERISTICS**

The effect of preloading and deep mixing with cement and lime on $m$, is illustrated in Figure 1(a) for Wattala Peat (an amorphous granular peat) and in Figure 1(b) for Madiwela Peat (a fibrous peat) respectively. Both peats possessed the same organic content and high void ratios but the degree of humification is higher in Wattala amorphous Peat. The curves in the two graphs present the variation of $m$, with stress levels for untreated peat (peat only), preloaded peat (reloaded) and peats mixed with different percentages of cement and lime (5% cement, 10% cement, 15% cement and 15% lime). The results show that mixing with 5% cement gives significant improvement in the amorphous peat from Wattala. The improvements achieved were of the same order as that achieved by preloading. But for the fibrous peat from Madiwela there is no significant improvement even for 15% cement mixing and 15% lime mixing. However, there is a significant improvement in Madiwela fibrous Peat by preloading as indicated by the curve labeled “reloaded”. Further details of the tests are presented in Munasinghe (2001).

Another series of tests done with Peliyagoda peat – an amorphous granular peat with lower initial water content has shown that the addition of 15% of lime has caused a significant improvement of coefficient of volume compressibility (Priyankara et al 2000). The improvements achieved there were of the same order as that achieved by preloading.

Another index that can be used to assess the improvement of primary consolidation characteristics is the compression index ($C_v$) and the recompression index ($C_c$). These parameters can be derived through the $e$ vs log $p$ plot. The plots done for Wattala amorphous peat and Madiwela fibrous peat are presented in Figure 2 (a) and Figure (b) respectively. All the loading, unloading and reloading increments are presented in the graphs. The graphs corresponding to natural peat and peat mixed with 5% of cement are drawn together in one plot (Figure 2 a) for Wattala amorphous peat. The graphs of natural peat and peat mixed with 15% cement are drawn together in one plot (Figure 2 b) for Madiwela fibrous peat. With both types of peat, it can be seen that the recompression index $C_c$ is much smaller than the compression index $C_v$. The ratio of $C_v / C_c$ is 0.05 for Wattala amorphous peat and is 0.09 for
Madiwela fibrous peat. Thus it is clear that the preloading can cause a significant improvement in primary consolidation characteristics in both types of peat.

With the mixing of 5% of cement the $C_v$ values were considerably reduced in Wattala amorphous peat. But even after the mixing of 15% of cement not much of an improvement is achieved in Madiwela fibrous peat. This indicates that the mixing with cement is not that effective for a fibrous peat. This behaviour is further confirmed by the data in Table 2 where the compression ratio $C_v/(1+e_0)$ values were compared. The value of the recompression ratio $C_v/(1+e_0)$ is given in the row labeled "reloaded".

It can be seen that for the Wattala amorphous peat the recompression ratio for untreated peat and the compression ratio for the 5% cement mixed peat were of the same order. This is an alternate way of illustrating that the primary consolidation characteristics were improved to the same level by the two techniques. For the fibrous Madiwela peat compression ratios for the cement and lime mixed cases were similar to the compression ratio of untreated peat indicating that the mixing technique is not effective. But the recompression ratio was much smaller illustrating that the preloading is effective.

![Figure 1](image)

(a): For a Amorphous Granular Peat

(b): For a Fibrous Peat

**Figure 1 – Effects of Improvement on $m_v$**
Figure 2 – Illustration of Effect of Improvement using $e$ vs $\log \sigma$ Plot

<table>
<thead>
<tr>
<th>Peat</th>
<th>Type</th>
<th>Natural Moisture Content</th>
<th>Organic Content</th>
<th>PH Value</th>
<th>Specific Gravity</th>
<th>Initial Void Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattala Peat</td>
<td>Amorphous Granular</td>
<td>387.00</td>
<td>29.00</td>
<td>2.60</td>
<td>2.23</td>
<td>8.63</td>
</tr>
<tr>
<td>Madiwela Peat</td>
<td>Fibrous</td>
<td>297.00</td>
<td>34.80</td>
<td>2.99</td>
<td>1.87</td>
<td>5.55</td>
</tr>
<tr>
<td>Peliyagoda Peat</td>
<td>Amorphous Granular</td>
<td>98.05</td>
<td>24.00</td>
<td>2.85</td>
<td>2.18</td>
<td>2.14</td>
</tr>
</tbody>
</table>

Table 1- Basic Properties of Different types of Peat used
<table>
<thead>
<tr>
<th>Peat Type</th>
<th>Method of improvement</th>
<th>Curing Time Period (wks)</th>
<th>C_s/(1+e_s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amorphous Peat -</td>
<td>Non Improved</td>
<td>-</td>
<td>0.3644</td>
</tr>
<tr>
<td>Wattala</td>
<td>Reloaded</td>
<td>-</td>
<td>0.0527</td>
</tr>
<tr>
<td></td>
<td>5% cement mixed</td>
<td>2</td>
<td>0.0365</td>
</tr>
<tr>
<td>Fibrous Peat -</td>
<td>Non Improved</td>
<td>-</td>
<td>0.2516</td>
</tr>
<tr>
<td>Madiwela</td>
<td>Reloaded</td>
<td>-</td>
<td>0.0962</td>
</tr>
<tr>
<td></td>
<td>5% cement mixed</td>
<td>4</td>
<td>0.2625</td>
</tr>
<tr>
<td></td>
<td>10% cement mixed</td>
<td>4</td>
<td>0.3717</td>
</tr>
<tr>
<td></td>
<td>15% cement mixed</td>
<td>4</td>
<td>0.1831</td>
</tr>
<tr>
<td></td>
<td>15% lime mixed</td>
<td>4</td>
<td>0.3979</td>
</tr>
</tbody>
</table>

Table 2 – Variation of Compression Ratio with Different Types of improvements

COMPARISON OF IMPROVEMENTS ACHIEVED IN SECONDARY CONSOLIDATION CHARACTERISTICS

Peats are well known for very high secondary consolidation settlements. As such, the coefficient of secondary consolidation is an important property to be considered in the improvement process. A typical e vs log (time) plot obtained in a loading increment in one of the consolidation tests is presented in Figure 3. The shape of the graph is quite different to that obtained from an inorganic soft clay. The gradient of the graph is increasing with time in the peaty soil, whereas it would be decreasing in soft inorganic clay. If the C_s values were computed for different times, it shows a gradual increase with time (Figure 4).

![Remoulded Madiwela Peat with 5% cement](image)

Figure 3 – Void Ratio Variation with Time
Figure 4 – Increase of $C_0$ with Time

The $C_0$ values obtained towards the end of the load increment were extracted from different loading and reloading increments of different specimen and presented in Figure 5 and Figure 6. Figure 5 compares the effect of preloading and 5% of cement mixing had on the Wattala amorphous peat. The $C_0$ values for the 5% cement mixed peat were of the same order as that corresponding to the preloaded peat. There was a significant reduction when compared with the untreated peat (peat only). This is a clear indication that in Wattala amorphous peat both the preloading and deep mixing cement will bring about significant improvements in the secondary consolidation characteristics.

Figure 5 - Reduction of $C_0$

Figure 6 - Reduction of $C_0$
Figure 6 presents the comparison of the effects of preloading and addition of 5% cement, 10% cement, 15% cement and 15% lime on Madiwela fibrous peat. There was no significant effect shown on 10% cement addition, 15% cement addition and 15% lime addition to Madiwela fibrous peat. However, preloading has caused a significant reduction of $C_u$ values. Significant reduction of $C_u$ seen only over the last two loading increment of 5% cement mixed case (Figure 6) is somewhat unusual. The variation of $C_u$ with time for the two types of peat for a selected load increment (20 - 40 kN/m$^2$) is presented in Figure 7 and Figure 8.

**Figure 7** - Variation of $C_u$ with time

**Figure 8** - Variation of $C_u$ with time
It should be noted that there were no records of the level of improvements achieved in the primary and secondary consolidation characteristics of peat, in the research papers of Swedish and Finish geotechnical engineers, cited in this paper.

**IMPROVEMENTS ACHIEVED IN SHEAR STRENGTH**

Improvement of shear strength characters of peat were quantified through the undrained cohesion values determined. Only the fibrous Madiwela Peat were subjected to these tests. The testing was done after hardening periods of two weeks and four weeks. When the soil was very soft so that the preparation of sample for the triaxial tests was not possible, a laboratory Tor vane apparatus was used to estimate the shear strength. The variation of $C_u$ with the mixing of different percentages of cement and lime are presented in Table 4. A gradual increase of undrained shear strength could be seen with the increased percentage of cement added. However the improvements were not so high as those reported for inorganic clays.

Even with the organic clays and Peat much greater improvements were achieved by the Swedish and Finish geotechnical engineers in their recent research. Jeliscic et al (2000) reported that unconfined strength of Peats were increased from an initial range of 5 – 10 kN/m² to the range 40 – 150 kN/m², 30 days after stabilization.

The improvement of shear strength with the preconsolidation was studied by conducting consolidated undrained triaxial tests in the laboratory. The specimen were isotropically consolidated at different cell pressures and the deviator stress was applied under undrained conditions. The increase in undrained shear strength ($\Delta C_u$) due to the increase in cell pressures ($\Delta \sigma_3$) was found and the ratio $\Delta C_u/\Delta \sigma_3$ was evaluated. The variation of undrained consolidation $C_u$ with consolidation is presented in Table 5. The ratio $\Delta C_u/\Delta \sigma_3$ is found to be around 0.2. Further tests are to be conducted with fibrous and amorphous peat samples obtained from other sites.

<table>
<thead>
<tr>
<th>Test</th>
<th>Curing Time -4 weeks $C_u$ (kN/m²)</th>
<th>Curing Time -4 weeks $C_u$ (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peat Only</td>
<td>$5%$ (cement)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U/U Triaxial</td>
<td>-</td>
<td>12.00</td>
</tr>
<tr>
<td>Tor Vane Test</td>
<td>5.36</td>
<td>-</td>
</tr>
</tbody>
</table>

*Table 4- Improvement of Shear Strength due to Mixing*
<table>
<thead>
<tr>
<th>Consolidated Pressure (kN/m^2)</th>
<th>C_u/kN/m^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>11</td>
</tr>
<tr>
<td>50</td>
<td>17</td>
</tr>
<tr>
<td>75</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 5 - Improvement of Shear Strength due to Consolidation

CONCLUSIONS

Improvement of thick deposits of soft peaty clays is one of the major challenges faced by the Sri Lankan Geotechnical Engineers. The methods of improvement by mixing with cement and mixing with lime were tried under laboratory conditions and improvements achieved in consolidation characteristics and shear strength properties were evaluated. These were then compared with the improvements achieved in preloading.

Preloading is seen to cause significant improvements in both the primary and secondary consolidation properties on all types of peat at different levels of humification. Deep mixing with cement or lime has the advantage of being able to develop the strength within a period as short as four weeks. However, this method is found to be successful only in the case of amorphous peats that are with a high level of humification.

Although, much smaller than those reported in the case of inorganic clays and in the case of peat in recent research by Swedish geotechnical engineers some improvements were achieved in the undrained shear strength of fibrous Peats.

Research on the possible improvements achievable in peat and organic clays with deep mixing has commenced in Sweden and Finland around 1995. There were laboratory based studies as well as instrumented field studies conducted with cement / lime and other form of binders at the prestigious Swedish Geotechnical Institute. There were studies at University of Oulu in Finland also. Publications on these research are emerging only now. The binders made from different industrial by products were found to be less expensive and sometimes more effective than cement/lime. This is an important finding as more than 70% of the total cost of operation was attributed to the stabilizer cost.

In the Sri Lankan context such binders are not available and the investigations should be concentrated on the use of cement and lime. Experience gained in the research done to date indicates that cement is more effective. The method is seen to be less effective with fibrous peat. As the differentiations between the two types of peat can be done only visually and there could be changes even within a site, the practical application of this technique to a given site should be preceded by sufficient laboratory tests and field verifications.
The next logical step in this research is to conduct a well instrumented field study with the measurement of strength and consolidation characteristics of peat initially and at different times after the treatment. Some of the field mixing apparatus used in the research done by Swedish geotechnical engineers do not appear to be very sophisticated and it should not be too difficult to modify existing equipments to conduct this operation.

The preloading method of improvement takes a long time and the dynamic consolidation (DC) and dynamic replacement (DR) techniques cause considerable disturbance and may not be acceptable in urban areas. Finding dumping grounds for removed peat could be a major environmental problem encountered in the stone column technique. Finding suitable granular fill in large quantities is another difficult task to achieve.

The deep mixing technique makes use of the existing soil and improvements are achievable in around 30 days without creating any spoil. It does not create much vibration and disturbance and hence can be implemented even in urban areas. This technique is regarded as an environmentally friendly. Further investigations through laboratory and field studies could be very beneficial to the country and the industry participation and collaboration in this context is most welcome.

REFERENCES

1. Chng Wei Lim (1999), Behaviour of Chemically Improved Peat, Thesis submitted in partial fulfillment of the requirements of B. Eng. (Civil) Degree, National University of Singapore.


fulfillment of the requirements of M. Eng. (Geotechnical Engineering) Degree at University of Moratuwa.

