Laboratory Studies on the Properties of Stabilized Marine Clay from Kakinada Sea Coast, India

D. Koteswara Rao
Associate Professor

G.V.R. Prasada Raju
Professor

Ch. Sowjanya & J. Purnachandra Rao
Graduate Students-2009

Department of Civil Engineering
University College of Engineering
KAKINADA- 533 003:: INDIA.

ABSTRACT

India being peninsular country has large area coming under coastal region and also it has been the habitat for considerable percentage of population. The marine clays are generally found in the states of West Bengal, Orissa, Andhra Pradesh, Tamilnadu, Kerala, Karnataka, Maharashtra and some parts of Gujarat. Marine or soft clays exists in these region are weak and expansive in nature.
The present study deals with the engineering properties of the marine clay collected from Kakinada Sea Port Ltd, Kakinada, A.P, India. The Physical &Chemical properties, the strength characteristics and also the load carrying capacity of the Marine clay have been determined in this study before and after stabilization with GBFS and the detailed test results are also discussed.

KEYWORDS: Atterberg limits, Marine Clay, undrained Cohesion, load carrying capacity, optimum moisture content (OMC), fully saturated condition (FSC), GBFS.

1 INTRODUCTI0N

Generally, the natural water content of the marine clays is always greater than its liquid limit. The comprehensive review of literature shows that a considerable amount of work is related for the determination of Engineering behaviour of marine clay has been carried out worldwide almost since last 50 years. From the various contributions, the investigations on physical, chemical and mineralogical properties of marine clay conducted by Eden et al. (1957), Noorani (1984), Shridharan et al.(1989) , Mathew et al. (1997) and Chew et al. (2004) are worthy of note. Significant research on strength and stiffness characteristics was performed by Koutsoftas et al. (1987) and Zhou et al. (2005). Improving the strength of the marine clay by the stabilization technique was performed by Supakij Nontananandh et al. (2004). Countable study on engineering properties of marine clays was performed by Basack et al (2009).
Marine clay deposits of Kakinada were used for the testing with the aim to investigate its Engineering properties and further make suitable for foundation constructions or sub-grades over it. The soil was collected at shallow depths from the Kakinada Sea Ports limited, Kakinada, A.P, India and used for the investigation.

2 GEOTECHNICAL PROPERTIES

The saturated marine clay was collected from Kakinada Sea Ports limited, Kakinada, Andhra Pradesh state, India. The soil was initially air dried in open atmosphere prior to the testing. The various Geotechnical

properties i.e. particle size distribution, Differential free swell, swell pressure , atterberg limits, strength parameters, load carrying capacity, consolidation characteristics before and after stabilization using Granulated Blast Furnace Slag and visual characteristics are described in this study.

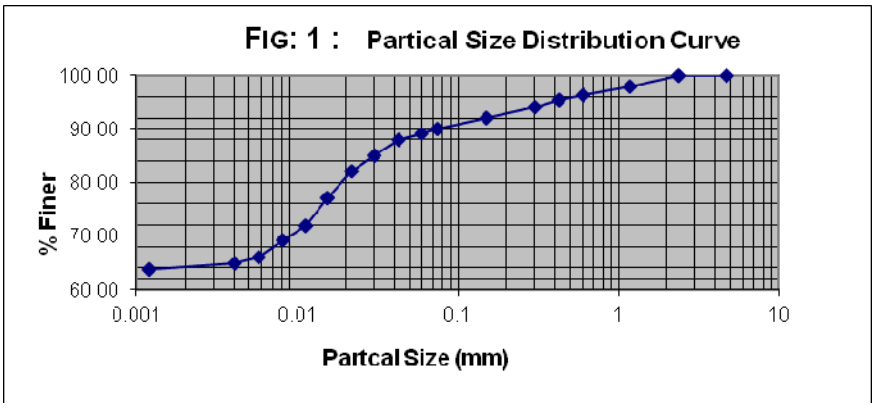
2.1 Visual Characteristics

The following properties are observed from visual classification in dry condition.

Colour -- Black colour
Odour -- Odour of decaying vegetation
Texture – Fine grained
Dry strength -- medium
Dylatancy -- Less Sluggish
Plasticity --Highly plastic
Classification -- Silty Clay

2.2 Grain Size Distribution

The sieve and Hydrometer tests were conducted to determine the grain size distribution of the marine clay as per IS 2720 (Part IV), 1965. The above tests have been conducted for the purpose of identification and classification of the soil.
The particle distribution curve was plotted and from which it was observed that the marine clay consists of 13% Sand, 23% Silt and 64% Clay by weight. The grain size distribution curve was shown in Fig.1.



2.3 Specific gravity

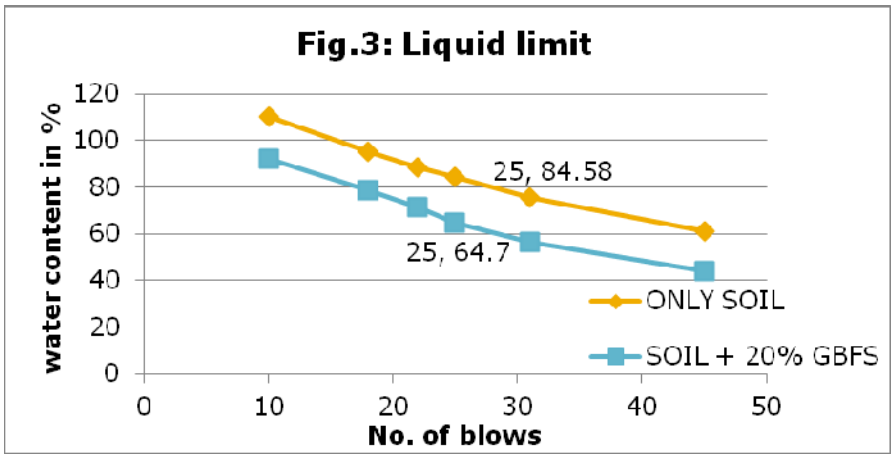
The Specific gravity of the marine clay was determined by using the density bottle method and it is observed from the results that the Specific gravity of the marine clay is 2.35.

2.4 Atterberg limits

The liquid limits of the marine clay was determined by using a Casagrande's liquid limit device as per the procedure laid down in IS 2720 (Part V), 1970 and atterberg limits were determined using standard methods before and after stabilization using GBFS.

Table No.1: Atterberg Limits of Marine Clay and Marine Clay +20% GBFS

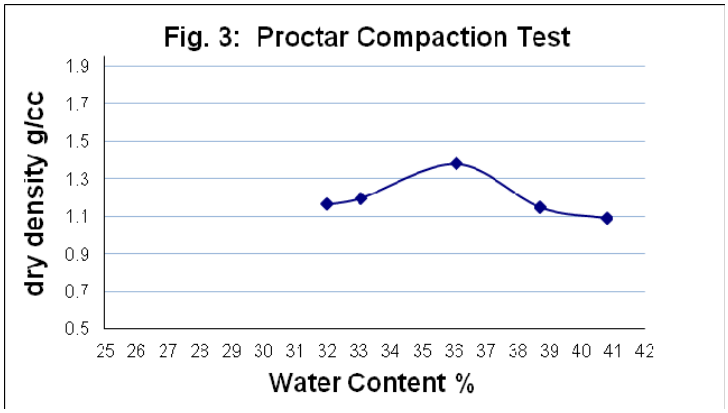
Sl.No.	Property	Marine Clay	Marine Clay + 20 % GBFS
1.	Liquid limit (%)	84.58	64.70
2.	Plastic limit (%)	45.69	28.90
3.	Shrinkage limit (%)	12.67	15.45
4.	Plasticity Index (%)	38.89	35.80



2.5 Compaction Properties

The standard Proctor compaction test was conducted on air dried marine clay soil samples with varying moisture content as per IS code: 2720 (part – XVI), 1979

In each test, the standard Proctor mould (size :100mm diameter and 117mm height) was filled with homogeneously mixed soil sample with water in three layers, each layer being compacted by 25 blows of a 25N rammer with a height of fall of 300mm The Plot was drawn between the moisture content and the dry density as shown in the Fig. 2, and the value of maximum dry density was observed as 1.377 g/cc with an optimum moisture content of 36.08%



2.6 Chemical and Mineralogical Properties

Various chemical properties of the Marine clay were determined and the test results are listed below.

Table No.2 : Chemical and Mineralogical Properties

Sl.No.	Name of the test	Result
1	PH Value at 25^0C	7.22
2	Electrical Conductivity	21000 Micromhos / cm
3	Solvable Salts	68250 micro gram/ grams of dry soil
4	Carbonates as Co_3	30 micro gram/ grams of dry soil
5	Organic Solids	14.54 %
6	Chlorides as Cl	27990 micro gram/ grams of dry soil

2.7 Un-consolidated Un-drained triaxial tests

The unconsolidated undrained Triaxial was conducted on the prepared remoulded marine clay soil samples at OMC condition. From the Mohr Circle diagram as shown in the Fig.4, the values of Cu and Φ were obtained as 0.120 KN / m^2 and 3.5^0 respectively. This small value of Φ is due to the presence of the sand and silt in the marine soil samples.

Table No. 3: Stress distribution by the Triaxial compression test:

Sample	Minor principal stress(σ_3) (kg/cm^2)	Deviator stress(σ_d) (kg/cm^2)	Major principal stress (σ_1) (kg/cm^2)
1	0.5	2.66	3.16
2	1	2.76	3.76
3	1.5	2.84	4.34

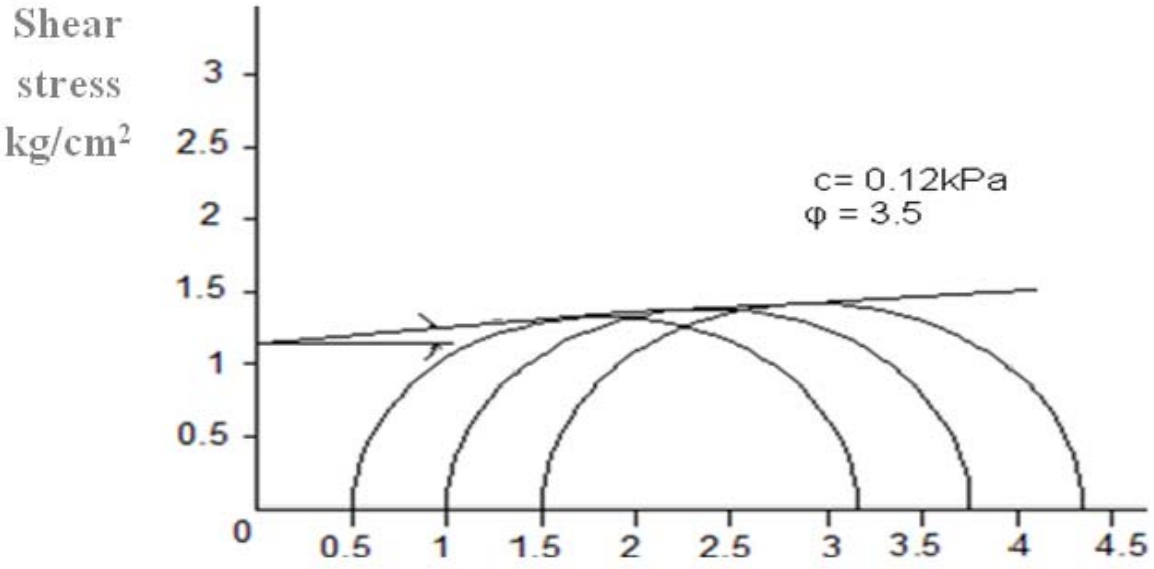


Fig.4: Mohr Circle diagram for U.U Triaxial test

2.8 Vane Shear Tests

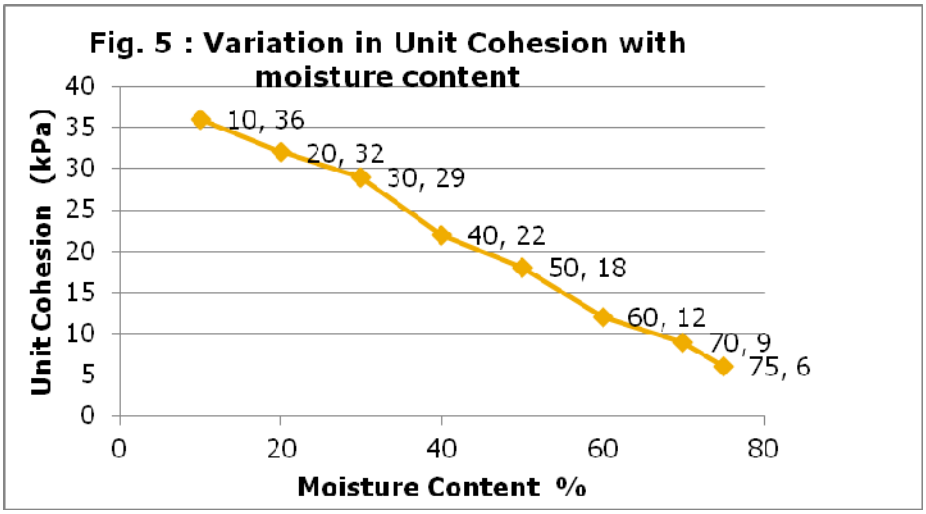
The Vane Shear tests were conducted on the remoulded marine clay soil samples to determine the Cohesion and angle of internal friction at fully saturated condition. It is observed as the value of Cohesion (C) is 3.5KN / m^2 and the value of Angle of inter friction (Φ) is 2^0.

2.9 Natural Water Content

The marine soil sample was well protected by using Polythene bags to avoid the evaporation losses of natural moisture content, while bringing from the Kakinada Sea Ports limited. The Natural Water Content of the marine clay was determined by using the "oven drying method", and which is a common method for determining the water content of the soil samples. It is observe that the Natural water Content as 96.15%.and which is higher than the liquid limit of the same marine clay i.e. 84.56%.

2.10 Unit Cohesion Determination

A series of vane shear tests has been conducted to investigate the variation in unit cohesion of the marine soil with increasing % of water content on a remoulded soil test beds by using Standard Proctor test. The plot of Unit Cohesion versus moisture content is shown in the Fig. 5.
It is observed that as the water content increases from 30 to 75 %, the Unit Cohesion Sharply dropped from 36kPa to as low as 6kPa.

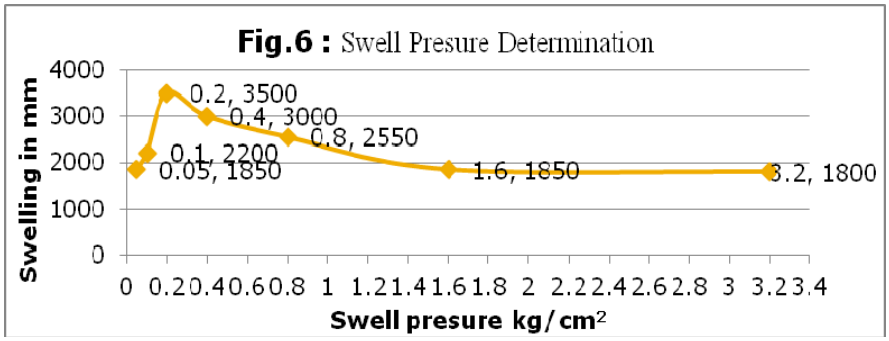


2.11 Differential Free Swell

The differential free swell of the marine clay has been determined by using the standard method and it is observed as 80%.

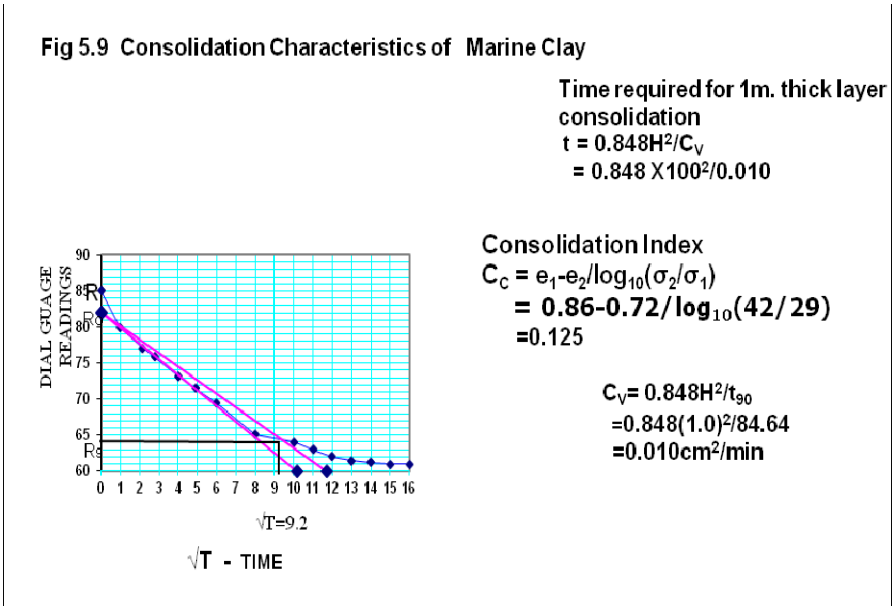
2.12 Swelling pressure

Swell pressure is defined as the maximum force per unit area that needs to be placed over a swelling soil to prevent volume increase**.** Swelling pressure is a very use full index of the trouble potential of an expansive soil. A swell pressure of less than 20 kN/m^2 may not be regarded as much consequence (Gopal Ranjan et.al;2006).
The Swell pressure of the marine clay was determined as per IS:2720 (Part XLI)-1977. The swell pressure of an undisturbed or remoulded soil is measured for no volume change condition. The method required continuous change on the soil specimen taken in a consolidation cell, so that the soil volume at any time is equal to its initial volume. The remoulded specimens are taken carefully at the density and moisture content of the field soil condition. The swelling pressure is determined as 1.6 kg/cm^2 or 160 kN/m^2**.** It is observed that the marine clay has moderate swelling characteristic.



2.13 Consolidation

The time required for the consolidation of one meter thick soil layer is determined by using a standard method. It is observed from the results as shown in the Fig., the time required for 90% consolidation is 588.8 days.



2.14 Collecting the Marine Clay from the Kakinada Sea Ports limited

Fig. 8 shows the collection of Marine Clay from Kakinada Sea Ports limited ,Kakinada, Andhra Pradesh State , India.

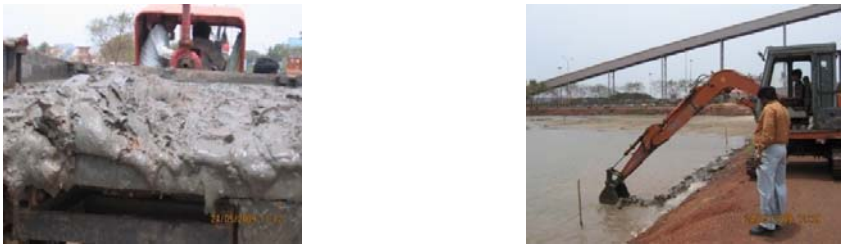


Fig. 8: The Author is collecting the Marine Clay from Sea Bed

2.3 LOAD CARRYING CAPACITY OF MARINE CLAY BEDS

2.3.1 Static Plate Load Test

The static plate load tests were conducted in a model tank of Circular in shape, having 56 cm diameter and 43 cm height as shown in the Fig. 9. The load is applied through the circular plate of 150mm diameter on to the Marine clay soil mix at OMC and FSC as shown in the Fig.9.

The steel tank is placed on the pedestal of compression testing machine. A thick metal plate is placed below the tank to ensure full support at its base. The Marine clay soil sample was compacted layer by layer of 15cm thickness for its optimum moisture content (OMC) and maximum dry density (MDD). A 15cm diameter circular metal plate with an extension rod is placed centrally over the prepared soil and a hydraulic jack of 5 tonnes capacity is centrally placed over the circular plate for conducting the static plate load test. Two dial gauges are placed on the metal plate welded to the extension rod on opposite sides to measure the deformation. The static Plate load test is carried out to determine the ultimate load carrying capacity of the Marne clayey soil foundation bed. Each pressure increment is placed only for no significant change in deformation between consecutive load increments. The testing is further continued till the failure for knowing the ultimate load bearing capacity of the Marine clayey soil foundation bed.

It is observed from the test results that the Ultimate load bearing capacity of the Marine clay foundation bed is 113.134 KN/m^2 at OMC with the settlement of 1.85 mm and the Ultimate load bearing capacity is 56.567KN/m^2 with the settlement of 3.65 mm at FSC.

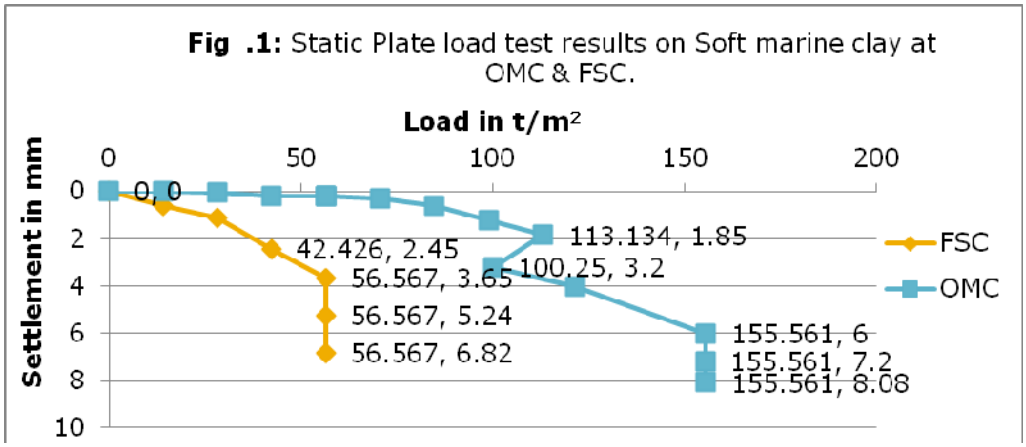


Fig. 9: Author is conducting the Static Plate Load test

CONCLUSIONS

The following conclusions are drawn based on the laboratory studies carried out on this study.

- The present study explains the knowledge about the Soft Marine Clay in connection with its Engineering Characteristics. It is noticed that the collected marine clay is blackish in colour, less sluggish, highly plastic and Silty Clay.

- It is observed that the liquid limit, plastic limit and the plasticity index were significantly high and the optimum moisture content was below the plastic limit.
- It is observed from the chemical analysis, the marine clay was found to possess significant proportion of carbonate content, organic matter content, cat ion exchange capacity and marginally alkaline.
- It is noticed from the U.U Triaxial test of a remoulded marine clayey soil sample, the value of Cohesion and Angle of internal friction were estimated as $0.12KN/m^2$ and 3.5^0 respectively.
- From the vane shear tests it was also observed that with the increase in moisture content , the unit cohesion of the soil sharply dropped down to a value as low as 6kPa.
- The load carrying capacity of the Marine Clay is high at its OMC to compare with FSC.
- It is observed from the test results that the time required for 90% consolidation is 311.6 days.
- It is noticed from the test results that the marine clay is fall under the category of moderately swelling soil and the Swell Pressure is 160 kN/m^2.

REFERENCES

[1] Basack and Purkayastha (2009), "Engineering properties of Marine Clays from the eastern coast of India", Journal of Engineering and Technology Research Vol.1 (6), pp.109-114, September, 2009.
[2] Gopal Ranjan and A.S. R. Rao (2006), "Basic and Applied Soil Mechanics", New Age International Publishers.
[3] Hyde AL,Yasuhara K, Hirao K (1993), "Stability Criteria for Marine Clay under Cyclic load" J. Geotech. Eng. ASCE 119(11):1771-1789.
[4] Kagawa T (1993), "Moduli and Damping Factors of Soft Marine Clays", J. Geotech. Eng. ASCE 118(9):1360-1375.
[5] Law. K.T (1979), "Triaxial – Vane tests on a Soft Marine Clay", Can. Geotech. J., 16,829-830.
[6] Narasimha Rao. S and Paul K (1996),"Permeability Studies in Marine Clays Stabilized with lime Column", International Journal of offshore and Polar Engineering ,Vol.6,No.3, September 1996(ISSN 1053-5381).
[7] Shridharan A, Rao SM, Chandrasekaran S (1989), "Engineering Properties of Cochin and Mangalore Marine Clays", Indian Geotech, J.1:265-278.
[8] Silvestri. V (1979), "Triaxial – Vane tests on a Soft Marine Clay", Can. Geotech. J., 16,828-829.
[9] Soo-Sam Kim et al (2007), "The Field Experimental Study on Improvement of Soft Marine Clay by EK – Cementation Technique", Proceedings of the seventeenth (2007) International Offshore and Polar Engineering Conference Lisbon, Portugal, July 1-6, 2007.
[10] Supakij N, Sanupong B et al (2004), "Strength Development of Soft Marine Clay Stabilized with Cement and Fly Ash" , Kasetsart J.(Nat.Sci.) 38:539-552.
[11] Thiam-Soon Tan et al (2002), "Properties of Singapore Marine Clay Improved by Cement Mixing", Geo-Tech Testing Journal, Dec2002, Vol.25, No.4.