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A Study on Consolidation Behaviour of Organic Soil Stabilized using Waste Plastic Fibres and Quicklime

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ABSTRACT
Constructions on organic soils are related to many problems due to their high compressibility, low shear strength and insufficient bearing capacity. The settlements in these soils often appear very quick and also continue for a long time. However, the organic soils have to be exploited as subsoil for many constructions. In this study, the organic soil collected from Ooty is stabilized using Waste Plastic Fibres with varying fiber content (0%, 0.1%, 0.25%, 0.5% and 0.75%) and different Aspect Ratio (AR - 12, 24, 48). The natural moisture content of the organic soil is taken as the water content for all the stabilization tests carried out. The Quicklime is tested for its optimum percentage for the soil (5%) and added in constant percentage as Binder. This research is mainly focused on consolidation behaviour of the organic soil for each varying percentage of plastic fibres with optimum percentage of quicklime for curing period of 7, 14 and 28 days. Overburden pressure of 30kPa is given for each soil proportion during curing process. For each proportion of stabilised soil, the Compressive strength is determined using Unconfined Compressive Strength test and the consolidation parameters are studied using one-dimensional consolidation test. The results show that there is a marked improvement in the strength and consolidation behaviour of the soil.

Keywords
organic soil; stabilization; plastic fibres; aspect ratio; quicklime; curing period; overburden pressure; unconfined compressive strength; one-dimensional consolidation; consolidation parameters

1. INTRODUCTION
The consolidation of compressible soil is of concern to engineers engaged in the design and construction of foundations, embankments, bridge abutments, earth dams, fills, pavements, etc,. Organic soils commonly occur as soft, wet, unconsolidated surficial deposits that are an integral part of the wetland systems. These types of soil give rise to geotechnical problems in the area of sampling, settlement, stability, in-situ testing, stabilization and construction. There is therefore a tendency to either avoid building on these soils, or when this is not possible, to simply remove or replace soils, which in some instances can lead to possibly uneconomical design and construction alternatives. In many cases, these soils have to be exploited as subsoil for many constructions with suitable stabilizers.

For the successful design, construction and performance of structures on marginal soils, it is crucial to predict the geotechnical behavior in terms of settlement, shear strength and stability with respect to time.

Plastic being a most common waste material, the stabilization using waste plastic fibres is an economic method where use of waste materials as plastic which is found accessibly.

Soil stabilization significantly changes the characteristics of a soil to produce long-term permanent strength and stability. Lime, either alone or in combination with other materials, can be used to treat a range of soil types. The mineralogical properties of the soils will determine their degree of reactivity with lime and the ultimate strength that the stabilized layers will develop. In general, fine-grained clay soils (with a minimum of 25 percent passing the #200 sieve (75µm) and a Plasticity Index greater than 10) are considered to be good candidates for stabilization. Soils containing significant amounts of organic material (greater than about 1 percent) or sulfates (greater than 0.3 percent) may require additional lime and/or special construction procedures.

The results of the research done by Bujang (2005) show that the addition of the chemical admixtures, cement and lime, can improve the engineering properties of tropical peat soil, especially after a long curing period. However, it is also found that high organic content of the soil negates the positive effect of the cement and lime in improving the mechanical properties of the soil. When comparing the performance of the cement and lime as a chemical admixture for the tropical peat soil, the cement appears to perform better than hydrated lime.

The results of the study done by Mohamed, A. Sakr (2008) indicate that the soft clay of high organic content of 14% can be stabilized satisfactorily with the addition of 7% lime. The results also demonstrate that the range in the mineralogical content and soil fabric of high organic lime-treated soft clay improve soil plasticity, strength and compressibility.

Many researches are being done on improvement of strength and consolidation properties of the organic soils using Quicklime as a potential stabilizer.

2. EXPERIMENTAL PROGRAMME

2.1 Material used
The materials used in the study are organic soil, waste plastic fibres and quicklime.

2.1.1 Organic Soil
The soil samples were collected from Coimbatore and Ooty regions. Out of five samples collected, the sample at latitude 11° 24'49" N and longitude 76° 42'30" E from the construction site near Executive Engineer PWD Office, Ooty founded to be suitable for the research. The physical properties of the soil are shown in the Table 1. The classification of soil is shown in Figure 1.

2.1.2. Plastic Fibres
Plastics used in the present study were collected from locally available plastic ropes. The average thickness of the fibre is 0.5mm. They were cut to the designed lengths (6mm, 12mm and 24mm) to achieve the Aspect Ratio of 12, 24 and 48 respectively. Specific Gravity of fibres is 0.89. The plastic fibres are hydrophobic, non corrosive and resistant to acids and alkalis.

2.1.3. Quicklime
Quicklime was used as binding agent in this research. Major chemical constituent of the lime is calcium oxide [CaO]. To reduce the carbonation effect due to humidity, the lime was kept in an airtight plastic container. The chemical composition of quicklime is: CaO-56.08%, SiO_2-4.02%, Fe_2O_3-1.96%, Al_2O_3-1.45% and Magnesia-0.94%

3. EXPERIMENTAL STUDY

3.1 General
The experimental study involves Unconfined Compressive Strength test and one dimensional consolidation tests on soil sample with varying percentage of Plastic Fibres (0%, 0.1%, 0.25%, 0.5% and 0.75%) by dry weight of soil and for different aspect ratios (12, 24 and 48). For all the proportions, the quicklime is added as constant percentage (5%) by dry weight of soil. The test samples are prepared and tested for the curing period of 7, 14 and 28 days.

3.2 Determination of Optimum Percentage of Quicklime

3.2.1 Eades & Grim pH Test (ASTM D 6276)
It is a quick test to determine the optimum lime content for the soil. This test identifies the lime content required to satisfy immediate lime-soil reactions and still provide significant residual calcium and a high system pH (about 12.4 at 25°C). This is necessary to provide proper conditions for the long-term pozzolanic reaction that is responsible for strength and stiffness development. For the study, the optimum value of quicklime is found to be 5% as shown in Figure 2.

3.2.2 UCS Test
The quicklime is determined for its optimum percentage for the collected OH soil sample by conducting Unconfined Compressive Strength (UCS) test for varying percentage of Quicklime with curing period of 7 days. The result is compared with the strength obtained for virgin OH soil sample and the optimum percentage of quicklime and the same is used for the entire study. The optimum value of quicklime (5%) determined using UCS test results is shown in Figure 3.

3.3 Sample Proportions
The soil samples are prepared for the following proportions.

1. Virgin soil at OMC
2. 0% Fibre + 5% Quicklime
3. 0.1% Fibre + 5% Quicklime (AR – 12, 24 and 48)
4. 0.25% Fibre + 5% Quicklime (AR – 12, 24 and 48)
5. 0.5% Fibre + 5% Quicklime (AR – 12, 24 and 48)
6. 0.75% Fibre + 5% Quicklime (AR – 12, 24 and 48)

Curing period of 7, 14 and 28 days is considered for all the proportions treated with Quicklime.

3.4 Sample Preparation
The samples were prepared by dry blending of soil and Quicklime. The natural moisture content is taken as the water content for each sample. In preparation of fibre reinforced samples, the fibres were added to moist mixture of soil-Quicklime. The samples were mixed manually with proper care to get homogeneous mix.

3.4.1 Selection of Overburden Pressure
The minimum pre-consolidation pressure of 30kPa makes the soil just stiff enough. The soil containing high organic matter shows large volume changes on loading and expulsion of water. In addition, the reconstituted organic soil is fully decomposed with normally loaded state and shows highly compressible phenomena. The reconstituted soils were prepared with a overburden pressure of 30kPa.

3.5 Tests Conducted

3.5.1 Unconfined Compressive Strength (UCS) Tests
The sample is directly prepared in the UCC sampler. Overburden pressure of 30kPa is given on the sampler (Figure 4). Test specimens of size 36mm x 72mm were prepared. Unconfined Compressive Strength tests were conducted in accordance with Indian Standards Specifications - IS 2720 (Part 10):1991.

3.5.2 One-Dimensional Consolidation Tests
The sample is prepared in cylindrical mould of diameter 70mm and overburden pressure of 30kPa is given on the mould (Figure 5). Specimens were prepared and tested in accordance with Indian Standards Specifications - IS 2720 (Part 15):1997.

4. TEST RESULTS AND DISCUSSIONS

4.1 General
Observations from Unconfined Compressive Strength tests and One-dimensional Consolidation tests have been analyzed to study the effect of Plastic Fibres on strength characteristics and consolidation behaviour of soil-Quicklime mixture.

4.2 Unconfined Compressive Strength Tests
The effect of Plastic Fiber inclusion on the unconfined compressive strength (UCS) was determined as a function of fiber content and length. The UCS tests were conducted for various proportions. At OMC of the soil, the compressive strength is 6kPa. The test results show that the Compressive Strength increases with increase in percentage of Plastic Fibres and also with increase in Aspect Ratio. For all the proportions, longer curing period gives better result. The proportion, 0.75% Fibre + 5% Quicklime with AR=48 for curing period of 28 days shows the maximum value of Unconfined Compressive Strength (331kPa). The Compressive Strength is increased about 55 times than that of virgin sample.

The UCS test result values are tabulated in Table 2. The variation of UCS values with fibre content for different Aspect Ratios and for varying curing period is shown in Figure 6.

4.3 One-Dimensional Consolidation Tests

The consolidation parameters such as Compression index (Cc), Coefficient of Compressibility (av), Coefficient of Consolidation (Cv), Pre-consolidation Pressure (P) and Coefficient of Permeability (k) are studied.

4.3.1 Compression index (C_c)

The variations of C_c with that of % and AR of Plastic Fibre for curing period of 7, 14 and 28 are shown Figure 7, 8 and 9 respectively. The values are tabulated in Table 3 and it can be signified that C_c has values ranging from 0.95 to 0.225. To predict the amount of settlement, knowledge on C_c of soil must be understood to solve the soil engineering problems (Lambe 1969).

4.3.2 Coefficient of Compressibility (a_v)

The variations of a_v with that of % and AR of Plastic Fibre for curing period of 7, 14 and 28 are shown Figure 10, 11 and 12 respectively. The values are tabulated in Table 4 and it can be signified that a_v has values ranging from 1.32cm^2/kgf to 0.23cm^2/kgf.

4.3.3 Coefficient of Consolidation (C_v)

The variations of C_v with that of % and AR of Plastic Fibre for curing period of 7, 14 and 28 are shown Figure 13, 14 and 15 respectively. The values are tabulated in Table 5 and it can be signified that C_v has values ranging from 0.024cm^2/min to 0.0017cm^2/min.

4.3.4 Pre-consolidation Pressure (P)

The variations of P with that of % and AR of Plastic Fibre for curing period of 7, 14 and 28 are shown Figure 16, 17 and 18 respectively. The values are tabulated in Table 6 and it can be signified that P has values ranging from 0.3kgf/cm^2 to 0.65kgf/cm^2.

4.3.5 Coefficient of Permeability (k)

The variations of k with that of % and AR of Plastic Fibre for curing period of 7, 14 and 28 are shown Figure 19, 20 and 21 respectively. The values are tabulated in Table 7 and it can be signified that k has values ranging from $8x10^{-6}$ cm/sec to $2x10^{-7}$cm/sec.

5. CONCLUSION

The following conclusions are drawn from the study.

- High Compressible Organic Soil sample is stabilised using Waste Plastic Fibres and Quicklime
- Optimum percentage of quicklime for the OH soil is found to be 5% by weight of dry soil by conducting Eades & Grim pH Test and UCS tests
- Unconfined Compressive Strength increases with increase in Lime content and Aspect Ratio. The proportion, 0.75% Fibre + 5% Quicklime with AR=48 for curing period of 28 days shows the maximum value of Unconfined Compressive Strength (331kPa). The Compressive Strength is increased about 55 times than that of virgin sample.
- Compression index, C_c decreased with increasing Plastic Fibre content and with addition of lime
- No observable trend for coefficient of consolidation (C_v) with increase in Plastic Fibres and with addition of lime
- Pre-consolidation pressure increased with increasing Plastic Fibre content and Lime
- Permeability decreases with increase in Plastic Fibre Content and Lime
- 0.25% of Waste Plastic Fibres + 5% quicklime proportion yields favourable Consolidation results
- For all the proportions, longer Curing period gives favourable result

Table 1. Properties of soil sample

S.NO	Properties	Results
1.	Natural Moisture Content, %	64
2.	Organic Content, %	33.3
3.	Specific Gravity	2.1
4.	Grain Size Analysis: % Gravel	1.8
	% Sand	3.2
	% Silt	17
	% Clay	78
5.	Soil Classification	**OH**
6.	Optimum Moisture Content, %	35
	Maximum Dry Density, g/cc	1.3
7.	Unconfined Compressive Strength, kPa	6
	Cohesion, kPa	3
8.	Free Swell index, %	55
9.	pH	7.40

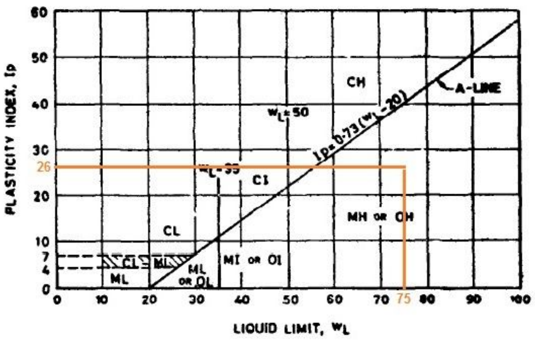

Figure 1. Plasticity Chart showing Soil Classification

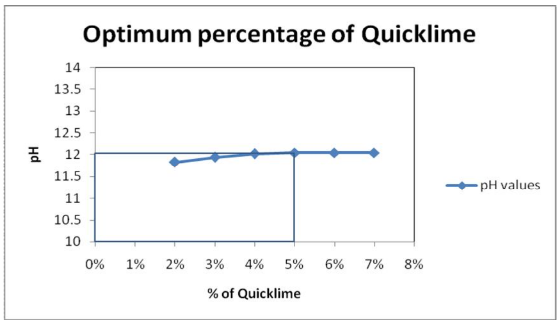

Figure 2. Eades & Grim pH Test

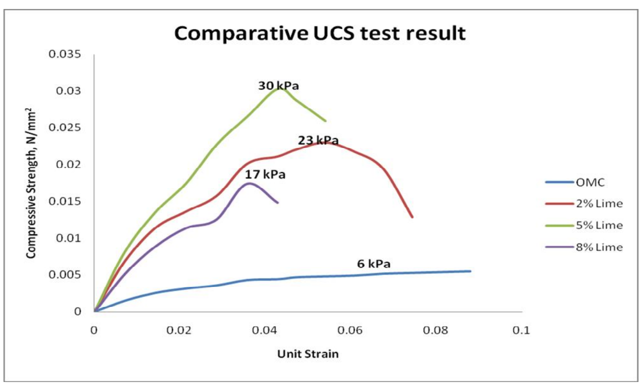

Figure 3. Comparative UCS Test result to determine Optimum % of Quicklime

Figure 4. Soil sample in UCC Sampler with Overburden Pressure

Figure 4. Soil sample in mould with Overburden Pressure for One-Dimensional Consolidation test

Table 2. Comparative UCS Test Results

Curing Period, Days	% Fibre / AR	0.1% Fibre	0.25% Fibre	0.5% Fibre	0.75% Fibre
7	**12**	32	37	47	74
14	**12**	156	165	166	180
28	**12**	215	233	240	235
7	**24**	36	48	54	102
14	**24**	162	171	170	186
28	**24**	219	235	256	266
7	**48**	43	59	69	124
14	**48**	171	184	179	201
28	**48**	234	252	317	331

OMC – 6kPa, **0% Fibre –** 30kPa (7), 150kPa (14), 165kPa (28)

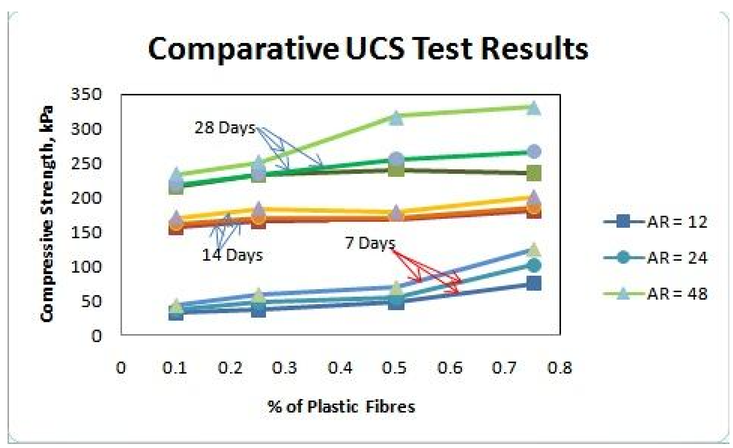

Figure 6. Comparative UCS Test Results

Table 3. Variation of C_c with % and AR of Fibres

Curing Period, Days	% Fibre / AR	0.1% Fibre	0.25% Fibre	0.5% Fibre	0.75% Fibre
7	**12**	0.07	0.045	0.06	0.065
14	**12**	0.065	0.045	0.06	0.06
28	**12**	0.05	0.04	0.05	0.05
7	**24**	0.03	0.03	0.04	0.06
14	**24**	0.03	0.025	0.03	0.05
28	**24**	0.03	0.0225	0.0225	0.03
7	**48**	0.045	0.045	0.04	0.05
14	**48**	0.04	0.04	0.035	0.045
28	**48**	0.03	0.03	0.035	0.05

OMC = 0.95, **0%Fibre** = 0.05 (7), 0.04 (14), 0.035 (28)

Table 4. Variation of a_v in cm^2/kgf with % and AR of Fibres

Curing Period, Days	% Fibre / AR	0.1% Fibre	0.25% Fibre	0.5% Fibre	0.75% Fibre
7	**12**	0.718	0.49	0.63	0.67
14	**12**	0.61	0.47	0.59	0.62
28	**12**	0.54	0.44	0.48	0.51
7	**24**	0.38	0.46	0.413	0.59
14	**24**	0.35	0.36	0.31	0.51
28	**24**	0.33	0.23	0.36	0.41
7	**48**	0.51	0.53	0.43	0.52
14	**48**	0.42	0.35	0.39	0.43
28	**48**	0.31	0.29	0.36	0.495

OMC = 1.32, **0%Fibre** = 0.4 (7), 0.38 (14), 0.35 (28)

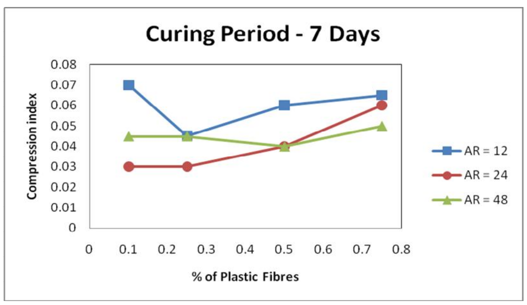

Figure 7. Variation of C_c – 7 Day Curing

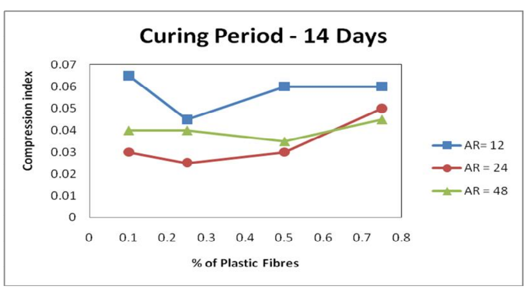

Figure 8. Variation of C_c – 14 Day Curing

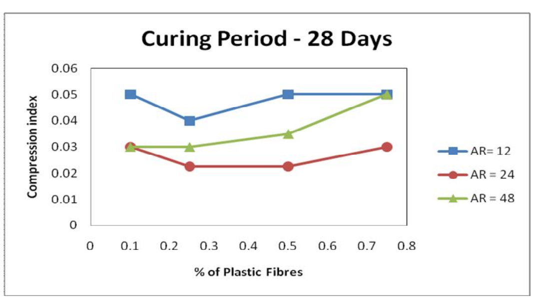

Figure 9. Variation of C_c – 28 Day Curing

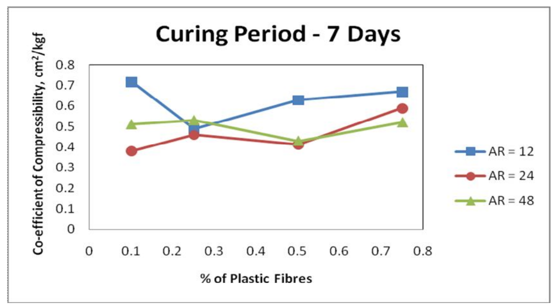

Figure 10. Variation of a_v – 7 Day Curing

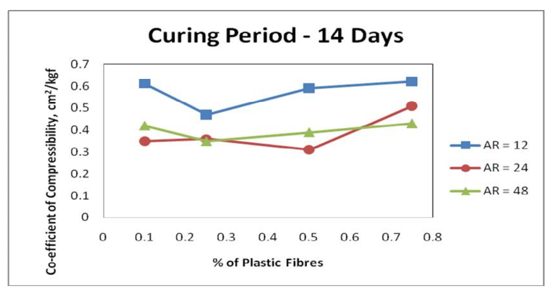

Figure 11. Variation of a_v – 14 Day Curing

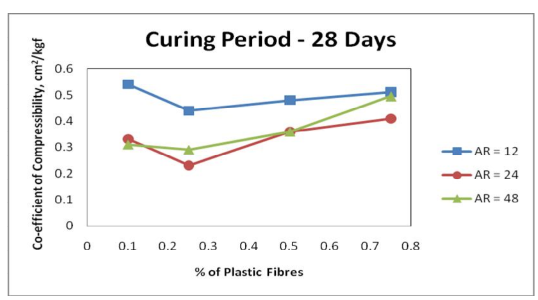

Figure 12. Variation of a_v – 28 Day Curing

Table 5. Variation of C_v in cm^2/min with % and AR of Fibres

Curing Period, Days	% Fibre / AR	0.1% Fibre	0.25% Fibre	0.5% Fibre	0.75% Fibre
7	**12**	0.023	0.0226	0.024	0.021
14	**12**	0.02	0.017	0.027	0.022
28	**12**	0.0098	0.0085	0.0089	0.0093
7	**24**	0.0036	0.0073	0.0076	0.0072
14	**24**	0.0052	0.0048	0.0056	0.0051
28	**24**	0.0032	0.002	0.0039	0.0017
7	**48**	0.0038	0.0035	0.0039	0.0037
14	**48**	0.0028	0.00255	0.0020	0.00253
28	**48**	0.0017	0.00253	0.002	0.00285

OMC = 0.077, **0%Fibre** = 0.034 (7), 0.046 (14), 0.018 (28)

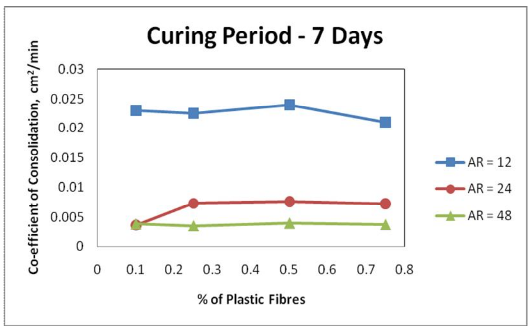

Figure 13. Variation of C_v – 7 Day Curing

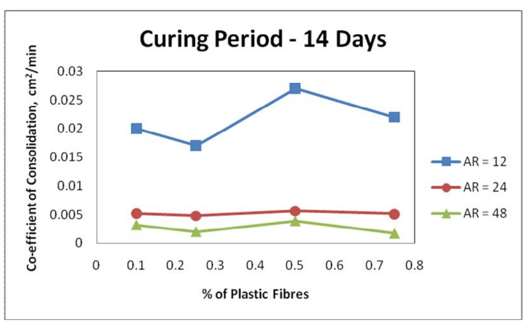

Figure 14. Variation of C_v – 14 Day Curing

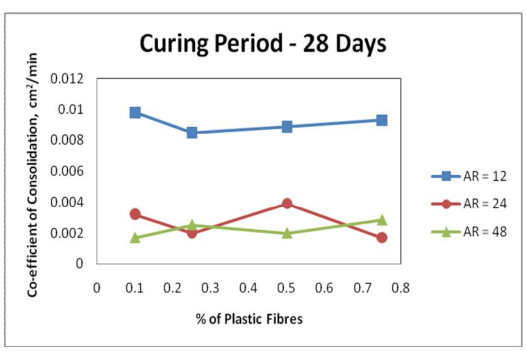

Figure 15. Variation of C_v – 28 Day Curing

Table 6. Variation of P in kgf/cm^2 with % and AR of Fibres

Curing Period, Days	% Fibre / AR	0.1% Fibre	0.25% Fibre	0.5% Fibre	0.75% Fibre
7	**12**	0.4	0.3	0.3	0.27
14	**12**	0.3	0.3	0.4	0.3
28	**12**	0.3	0.4	0.3	0.35
7	**24**	0.5	0.55	0.48	0.42
14	**24**	0.5	0.65	0.56	0.51
28	**24**	0.5	0.56	0.45	0.4
7	**48**	0.4	0.5	0.4	0.4
14	**48**	0.45	0.55	0.5	0.5
28	**48**	0.45	0.5	0.56	0.53

OMC = 0.35, **0%Fibre** = 0.3 (7), 0.35 (14), 0.45 (28)

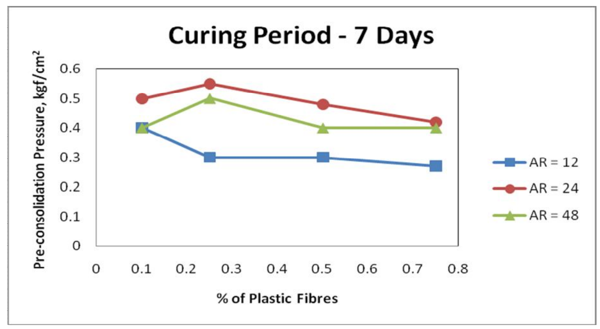

Figure 16. Variation of P – 7 Day Curing

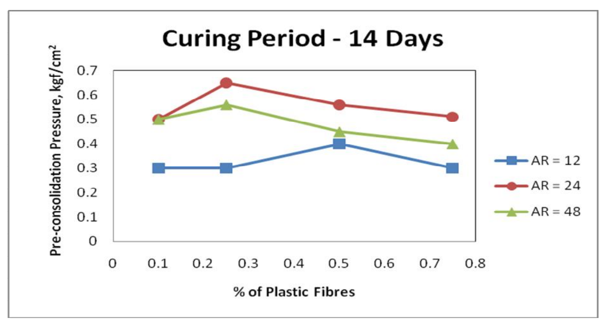

Figure 17. Variation of P – 14 Day Curing

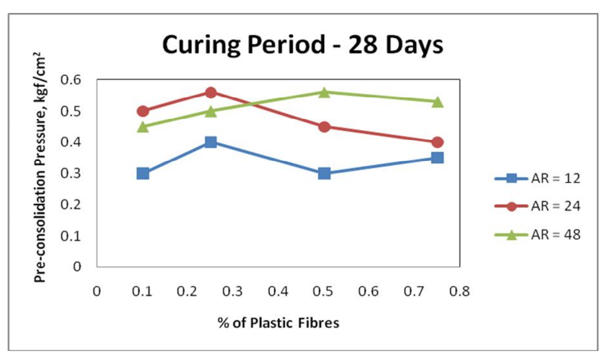

Figure 18. Variation of P – 28 Day Curing

Table 7. Variation of k in x10^{-6} cm/sec with % and AR of Fibres

Curing Period, Days	% Fibre / AR	0.1% Fibre	0.25% Fibre	0.5% Fibre	0.75% Fibre
7	**12**	5.4	3.7	2.2	6.2
14	**12**	3.6	1.8	2.23	4.78
28	**12**	2.7	3.03	2.12	4.19
7	**24**	0.75	0.67	0.7	0.72
14	**24**	0.68	0.52	0.6	0.54
28	**24**	0.267	0.3	0.52	0.5
7	**48**	1.583	1.79	2.51	2.97
14	**48**	0.846	1.14	2.08	2.41
28	**48**	0.367	0.388	1.44	1.69

OMC = 8.4, **0%Fibre =** 0.74 (7), 0.7 (14), 0.64 (28)

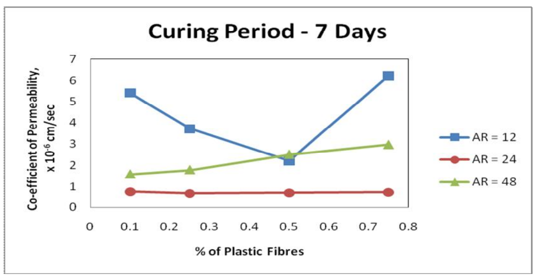

Figure 19. Variation of k – 7 Day Curing

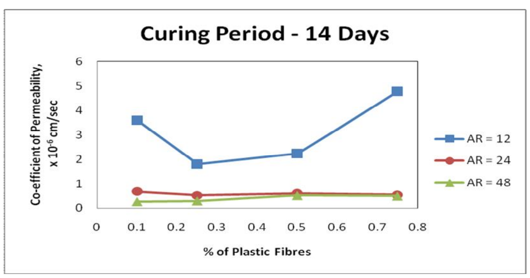

Figure 20. Variation of k – 14 Day Curing

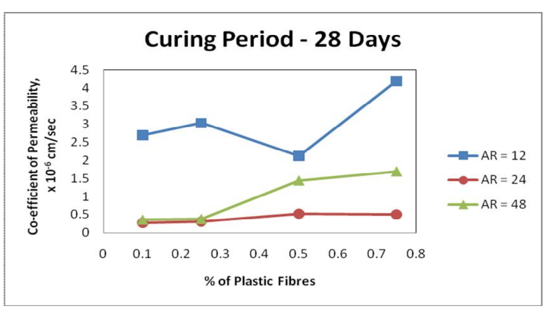

Figure 21. Variation of k – 28 Day Curing

REFERENCES

[1] Bujang B.K. Huat, Shukri Maail and Thamer A. Mohamed, "Effect of Chemical Admixtures on the Engineering Properties of Tropical Peat Soils," DOI:10.3844/ajassp.2005.1113.1120, American Journal of Applied Sciences, Volume 2, Issue 7, pp 1113-1120

[2] Crawford, C.B.,1986, "State of the Art: Evaluation and Interpretation of Soil Consolidation Tests," Consolidation of Soils: Testing and Evauation, ASTM STP 892, R.N. Yong and F.C. Townsend, Eds., American Society for Testing and Materials, Philadelphia, 1986, pp 71-103

[3] Mohamed A. Sakr, Mohamed A. Shahin, Yasser M. Metwally, 2008,"Utilization of Lime for Stabilizing Soft Clay Soil of High Organic Content,"DOI 10.1007/s10706-008-9215-2, Springer Science+Business Media B.V. 2008

[4] Ayyappan, S., Hemalatha, K., Sundaram, M., "Investigation of Engineering Behavior of Soil, Polypropylene Fibres and Fly Ash – Mixtures for Road Construction," International Journal of Environmental Science and Development, Vol.1, No.2, June 2010, ISSN:2010-0264

[5] Saranya, K., Muttharam, M., "Consolidation Stress Effect on Strength of Lime Stabilized Soil, "International Journal of Engineering Research and Applications, ISSN:2248-9622, Vol.3, Issue 5, Sep-Oct 2013, pp1515-1519

[6] Tahia Rabbee, Islm M. Rafizul, Md. Assaduzzaman, Muhammed Alamgir, "Investigate the Effect of Pre-consoliadtion pressure and organic content on the Shesr Strength and Compressibility Parameter of Reconstituted Soil," International Journal of Applied Sciences and Engineering Research, Vol.1 Issue 6, 2012, ISSN 2277-9442.

[7] Asst. Lec. Maha Hatem Nsaif "BEHAVIOR OF SOILS STRENGTHENED BY PLASTIC WASTE MATERIALS" Journal of Engineering and Development, Vol. 17, No.4, October 2013, ISSN 1813- 7822 Doctoral Thesis Helen Åhnberg

[8] "STRENGTH OF STABILISED SOILS– A LABORATORY STUDY ON CLAYS AND ORGANIC SOILS STABILISED WITH DIFFERENT TYPES OF BINDER" *Department of Construction Sciences* ISRN LUTVDG/TVSM--06/1020--SE (1-194) ISBN 978-91-628-6790-4 ISSN 0281-6679 Swedish Deep Stabilization Research Centre

[9] Abdul Wahed bin Masawi "EFFECTS OF ORGANIC CONTENT ON CONSOLIDATION PARAMETERS OF PEAT SOIL"Universiti teknologi Malaysia

[10] Zulkifli bin Ahamad "COMPRESSIBILITY AND SHEAR STRENGTH BEHAVIOUR OF PEAT SOIL IN SARAWAK"Faculty of Engineering, Universiti Malaysia Sarawak, 2005 IS 2720 (Part 15) -1986 - Consolidation parameters

[11] Dallas N. Little, Syam Nair "RECOMMENDED PRACTICE FOR STABILIZATION OF SUBGRADE SOILS AND BASE MATERIALS", Texas Contractor's Final Task Report for NCHRP Project 20-07 Submitted August 2009