Bearing Strength on the Effect of Cement-NP on Studied Soils

[1]Su Latt Hnin and [2]Phyu Phyu Lwin,
[1,2]Department of Civil Engineering, Pyay Technological University, Pyay, Myanmar

Abstract— This study presents stabilization of two different studied soils treated with cement-natural pozzolan. Soil samples are taken at about 3 ft depth from Yenangyaung Industrial Zone in Yenangyaung Township and Chaung Woong village in Patheingyi Township which are denoted by Soil A and soil B respectively. Laboratory tests are conducted to determine the engineering properties and strength characteristics of studied soils with and without cement and natural pozzolan. Specific gravity test, grain-size analysis, atterberg limit test and free swell test are performed to identify and classify the studied soils. Compaction test is used to obtain the optimum moisture content and maximum dry density. Studied soils are then tested for strength parameters such as triaxial shear test and california bearing ratio (CBR) test. According to Unified Soil Classification System (USCS), the studied soils are found as clayey sand in SC group and fat clay with sand in CH group. In order to determine optimum content of cement on the basic of MDD value, soils are mixed with cement. Cement contents are selected as 2%, 4% and 6% by weight of natural soil. Optimum contents of cement are 2% for SC soil and 4% for CH soil. Then, studied soils are stabilized with various percentages (4%, 8%,12%) of natural pozzolan on the basic of optimum content of cement. Atterberg limit test , compaction test, triaxial shear test, and CBR test are performed for these modified mixture.

Keywords*—Atterberg Limit, Cement, CBR, Compaction, Natural Pozzolan*

I. INTRODUCTION

Soil is used as a construction material in various civil engineering projects and it supports structural foundation. Thus, civil engineers must study the engineering properties of soil such as specific gravity, grain size distribution, consistency limits, compressibility and shear strength and load-bearing capacity. Civil engineering works in highways, buildings, dams and other structures have strong relationship with soil. These structures need a strong and stable layer of foundation soil to build on. Therefore, soil must be able to carry imposed loads from any structure placed upon it without shear failure or destructive unallowable settlements. Thus, proper estimation of bearing strength of foundation soil is very essential for safety and performance of the structures. The poor engineering properties of soil create problems for construction projects. This soil requires to be stabilized. Soil stabilizations are implemented for improving soils, which have inadequate engineering properties. Soil stabilization refers to the process of changing soil properties to improve engineering properties of soil. Soil can be stabilized by mechanically or chemically. Mechanical stabilization means improving the soil properties by rearrangement of particles and densification by compaction, or by changing the gradation through addition or removal of soil particles. Chemical stabilization means improving the soil properties with chemical stabilizers such as cement, lime, fly ash, natural pozzolan, bitumen and enzyme etc. Two disturbed soil samples are mixed with various percentages of natural pozzolan and cement to stabilize and are performed various soil tests. Ordinary Portland cement and natural pozzolan (NP) are added to studied soils at 0 to 10% and 0 to 20% by weight of dry soil respectively. This paper presents the addition of cement-NP mixture to the studied soils will change the strength behaviour of these soils.

II. MATERIALS

A .Soils

The soil samples are taken at about 3ft depth from Magway Region and Mandalay Region which are denoted by soil A and soil B respectively. The studied soils was excavated, placed in plastic bags, and transported to the laboratory for preparation and testing. Laboratory tests were carried out to classify each type of soil.

B .Cement and Natural Pozzolan

The Ordinary Portland cement used was a commercially available cement typically used for construction purposes. Cement is the oldest binding agent since the invention of soil stabilization technology in 1960s. In this study ordinary Portland cement is used in my study. The natural pozzolan (NP) used in this investigation was collected from Natural Pozzolan Grinding Plant in Popa. The NP was ground in a laboratory mill to a specific surface area of 420 m^2/kg.

III. PERFORMED TEST RESULTS OF NATURAL SOILS

In order to determine the properties of natural soil before adding cement and natural pozzolan mixture, the following tests are performed. They are water content determination, specific gravity test, Atterberg limit test, compaction test, triaxial shear test and CBR test are performed. Soil samples are tested in Soil, Concrete Laboratory and Irrigation Technology Centre, Patheingyi Township, Mandalay.

A.Water-Content Determination

Water-content determination is a routine laboratory test to determine the amount of water present in a quantity of soil in terms of its dry weight. The values of water-content determination are 9.4% for soil A and 25.4% for soil B respectively.

B.Specific Gravity Test

Specific gravity is defined as the ratio of the unit weight of a given material to the unit weight of water.

The equation (1) is used to find the specific gravity of soil.

$$G_s = \frac{G_t W_s}{W_s + W_2 - W_1} \quad (1)$$

Where: G_s = Specific gravity of soil
G_t = Specific gravity of water at t; temperature
W_s = Weight of dry soil

W_1 = Weight of bottle plus water plus soil
W_2 = Weight of bottle plus water

The values of specific gravity are both 2.7 for soil A and soil B. For clay and silty soils, the specific gravity of soil ranges from 2.6 to 2.9. Therefore, the specific gravities of both soils are within the limits.

C. Grain-Size Analysis of Soil

Grain size analysis is the determination of the size range of particles present in a soil, expressed as a percentage of the total dry weight. The following methods are generally used to find the particle size distribution of soil.

1. Sieve Analysis is used for particle sizes larger than 0.075 mm in diameter.
2. Hydrometer Analysis is used for particle sizes smaller than 0.075 mm in diameter.

The grain size analysis of soil results are shown in Table I.

Table 1: Grain Size Analysis Test Results for Soil A and Soil B

Sample	Soil A	Soil B
Gravel (%)	0	0
Sand (%)	67.1	20.8
Silt (%)	24.5	67.1
Clay (%)	8.4	12.1
F_{200}	32.9	79.16
R_{200}	67.1	20.84
F_4	93.13	100
R_4 (GF)	0.06.87	0.0
$SF=R_{200} - R_4$	60.23	20.84
SF/GF	>1	-

D. Atterberg Limit Test

The water content levels at which the soil change from one state to the other are the Atterberg limits.

They are the plastic limit (PL), liquid limit (LL), and shrinkage limit (SL). These limits are referred to as Atterberg Limits. The plasticity index is the difference of liquid limit and plastic limit. The following equation is used to find the plasticity index.

$$PI = LL - PL \tag{2}$$

E. Free Swell Test

Ten grams of oven-dried soil specimens passing No.40 sieve (0.425 mm openings) is placed in the graduated cylinders containing distilled water and kerosene. Sediment volumes are measured after complete sedimentation of specimens in respective fluid. It takes about 24 hours to 120 hours in distilled water. Kerosene is used instead of carbon tetrachloride since it is easily available in Myanmar. Table II shows classification of clays on the basis of their free swell ratio.

To calculate the free swell ratio the equation (3) is used.

$$FSR = \frac{V_w}{V_k} \tag{3}$$

Where, FSR= Free Swell Ratio

V_w = Sediment volume of soil in distilled water (cm^3)

V_k = Sediment volume of soil in kerosene (cm^3)

Table 2: Classification of clays on the basis of their free swell ratio

Free Swell Ratio	Clay Type	Soil Expansion
≤ 1.0	Non- swelling	Negligible
1.0 – 1.5	Mixture of swelling and non-swelling	Low
1.5 – 2.0	Swelling	Moderate
2.0 – 4.0	Swelling	High
> 4.0	Swelling	Very High

Free swell ratio of soil A and soil B are 1 and 1.6 respectively. From this result, two types of studied soils are negligible and moderate in soil expansively.

F. Modified Free Swell Index Test

This is performed by pouring 10 cm^3 of dry soil into a 100 cm^3 graduated jar filled with distilled water, noting the swelled volume of the soil after it comes to rest. Table III shows the soil classification on modified free swell index. It is calculated the following equation.

$$\text{Modified free swell index} = \frac{V - V_s}{V_s} \tag{4}$$

Where, V = Soil volume after swelling (cm^3)
V_s= Volume of soil solid (cm^3)

Table 3: Soil Classification Scheme Based on Modified Free Swell Index

Modified Free Swell Index	**Swelling Index**
< 2.5	Negligible
2.5 to 10	Moderate
10 to 20	High
>20	Very High

Modified free swell index results for soil A and soil B are 1.70 and 3.05 respectively. Therefore, soil A is non-swelling and soil B is moderate in soil expansively respectively.

G. Classification of Soil According to USCS

According to the results and Unified Soil Classification System, the studied soil A is in SC group and sub-group name is sandy silt with clay. Soil B is in CH group and sub- group name is sandy fat clay.

H. Compaction Test

Compaction is the densification of soil by removal of air, which requires mechanical energy. This test is used for determining optimum moisture content and maximum dry density.

I. Triaxial Shear Test (UU) Test

There are three types of triaxial shear tests. They are Consolidated-drained (CD) test, Consolidated-undrained (CU) test and Unconsolidated-undrained (UU) test. In this study, (UU) test is used because soil sample is loaded to failure in (10 to 20 min). Soil specimens passing ASTM sieve No.4 (4.75mm) are mixed with water depend on optimum moisture content from compaction test. Then, three soil specimens about 3.5cm in diameter and 8.75cm long are made. This test is used for determining internal friction angles, Ø and cohesion, c of soil sample.

$$\tau = c + \sigma \tan \phi \qquad (5)$$

J. California Bearing Ratio (CBR) Test

The California bearing ratio (CBR) is defined as the rate of the force per unit area required to penetrate a soil mass with a standard circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for the corresponding penetration of a standard material. Classification system on the basis of CBR number is described Table IV.

Table 4: Classification System on the Basis of CBR Number

CBR No	General Rating	Uses
0-3	Very Poor	Subgrade
3-7	Poor to Fair	Subgrade
7-20	Fair	Subbase
20-50	Good	Base, Subbase
>50	Excellent	Base

IV. PERFORMED TEST RESULTS OF CEMENT-NP TREATED SOIS

Various percentages are selected to study the effect of variation of cement-NP mixture treated with studied soils. 2% cement content is constant and treated with (4%, 8%, 12%) of NP mixture for soil A. For soil B, 4% cement content is constant and treated with (4%, 8%, and 12%) of NP mixture.

Table 5: Atterberg Limit of soil A treated with cement and NP mixture

Soil Type	Percentages of Cement and NP Mixture (%)	LL (%)	PL (%)	PI (%)
Soil A	Natural	30.2	15.4	15.8
	C2NP4	34.0	16.5	17.5
	C2NP8	33.6	17.9	15.7
	C2NP12	32.2	19.7	12.5
Soil B	Natural	52.3	25.3	27.0
	C4NP4	38.8	27.2	11.6
	C4NP8	38.1	28.5	9.6
	C4NP12	37.7	30.1	7.6

A. Atterberg Limit Test Results of Studied Soils Treated with Cement-NP Mixture

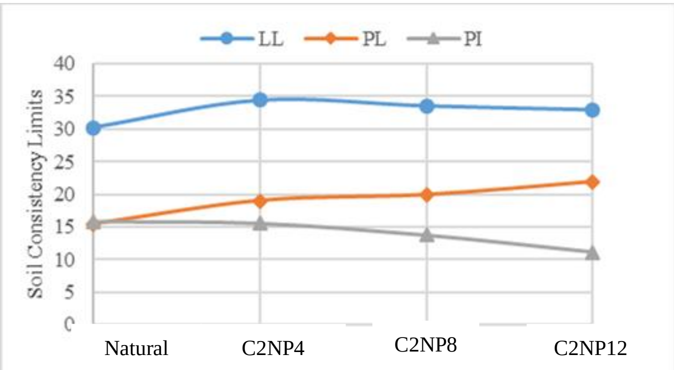

Fig.1. Variation of Consistency Limits with Cement-NP for Soil A

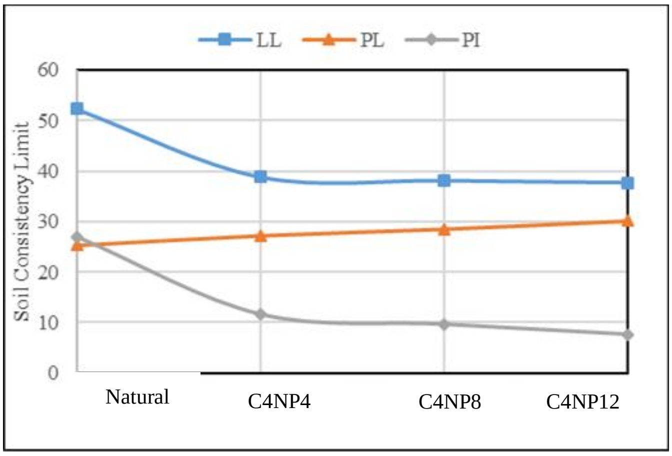

Fig.2. Variation of Consistency Limits with Cement-NP for Soil B

Results of consistency limit tests of cement-NP mixture treated soil A and soil B are shown in Table V. The effects of cement and NP mixture on the soil consistency of the soil A and soil B are illustrated in Figure 1 and Figure 2 respectively.

B. Compaction Test Results Studied Soils Treated with Cement-NP Mixture

Compaction test is used to determine the optimum moisture content and maximum dry density. Compaction test results of natural soil and treated soils with cement and NP are shown in Table VI. Variation of optimum moisture contents and maximum dry density with cement- NP are described in Figure 3 for soil A and Figure 4 for soil B.

Table 5: Compaction Test Results of studied soils treated with cement and NP mixture

Soil Type	Percentages of Cement-NP	OMC (%)	MDD (pcf)
Soil A	Natural	12.2	123.5
	C2NP4	11.5	124.2
	C2NP8	12.5	121.4
	C2NP12	13.5	121.0
Soil B	Natural	22.3	92.8
	C4NP4	19.0	105.3
	C4NP8	21.5	104.5
	C4NP12	23.0	104.1

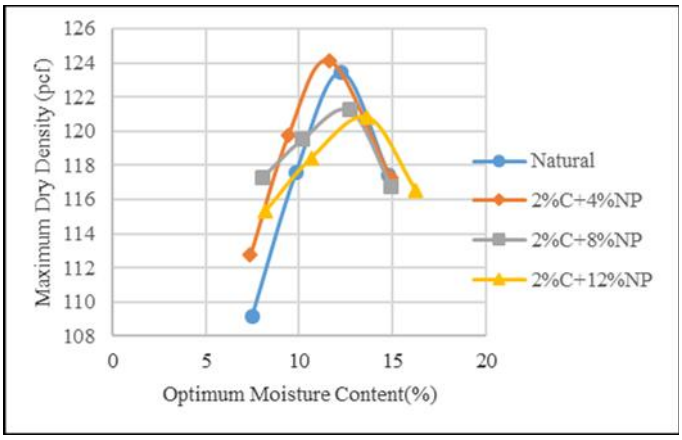

Figure.3. OMC and MDD Relation Curve for Soil A

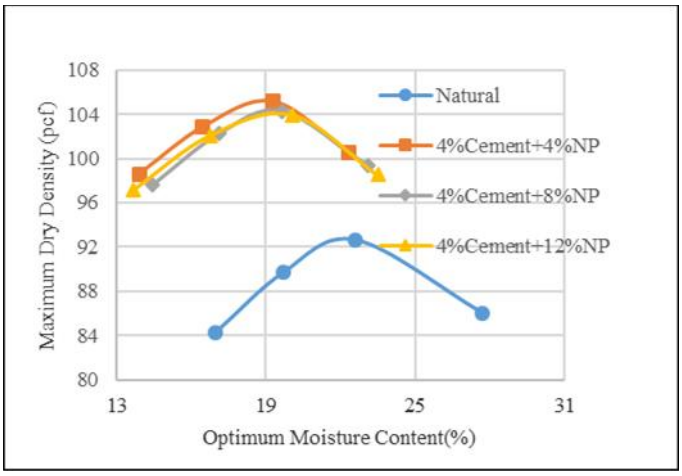

Figure.4. OMC and MDD Relation Curve for Soil B

C. Triaxial Shear Test Results

Shear strength parameters of two studied soils are evaluated by stabilization with various percentages of cement and NP mixture. Triaxial shear (UU) test are performed. Variation of cohesion and internal friction angle with cement-NP are shown in Table VII. Figure 5 and Figure 6 are illustrated the effect of cement and NP mixture on cohesion and internal friction angle of treated soil A and soil B respectively.

Table 7: Triaxial Test Results of studied soils treated with cement and NP mixture

Soil Type	Percentages of Cement-NP	Cohesion (kg/cm^2)	Internal Friction Angle (degree)
Soil A	Natural	0.82	21·17'
	C2NP4	1.27	32·49'
	C2NP8	0.99	32·00'
	C2NP12	0.88	31·36'
Soil B	Natural	0.95	10·0'
	C4NP4	0.73	25·6'
	C4NP8	1.35	19·1'
	C4NP12	1.4	18·26'

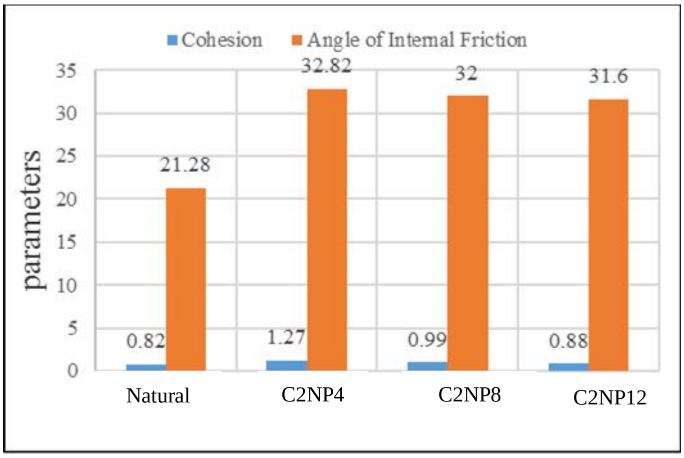

Figure 5. UU Test Results for Cement-NP Treated Soil A

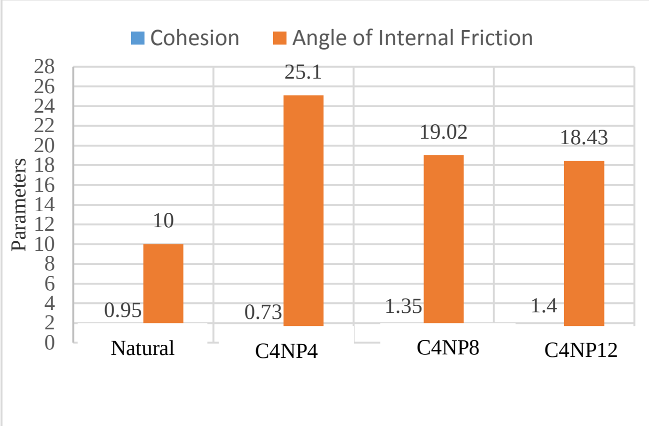

Figure 6. UU Test Results for Cement-NP Treated Soil B

D. California Bearing Ratio Test Results

CBR test results of natural soil and cement-NP treated soil A and soil B are shown in Table VIII.

Table 8: CBR Test Results of CEMENT-NP TREATED Studied soils

Soil Type	Percentages of Cement and NP Mixture (%)	CBR (%)		Uses
Soil A	Natural	Unsoaked	13.3	Subbase
		Soaked	12.8	Subbase
	C2NP4	Unsoaked	72	Base
		Soaked	87	Base
	C2NP8	Unsoaked	84	Base
		Soaked	93	Base
	C2NP12	Unsoaked	99	Base
		Soaked	102	Base
Soil B	Natural	Unsoaked	7.2	Subgrade
		Soaked	5.3	Subgrade
	C4NP4	Unsoaked	25	Subbase, Base
		Soaked	117	Base
	C4NP8	Unsoaked	18	Subbase
		Soaked	91	Base
	C4NP12	Unsoaked	27.2	Subbase, Base
		Soaked	71	Base

E . Prediction of Bearing Values Based on CBR Values

Approximate interrelationship of bearing values of subgrade for pavement structures are taken from figure 20.8 in Traffic and Highway Engineering Book (Fourth edition). Table IX and Table X describe the results of bearing values based on CBR values for soil A and soil B treated with selected percentages of cement and natural pozzolan (NP) mixture.

Table 9: Bearing Values Results Of Cement-Np Treated Soil A

Percentages of Cement and NP Mixture (%)	CBR (%)	Bearing Values (ton/ft^2)
Natural	Unsoaked	1.5
	Soaked	1.45
C2NP4	Unsoaked	3.98
	Soaked	5.0
C2NP8	Unsoaked	4.69
	Soaked	5.27

C2NP12	Unsoaked	5.72
	Soaked	5.78

Table 10: Bearing Values Results Of Cement-Np Treated Soil B

Percentages of Cement and NP Mixture (%)	CBR (%)	Bearing Values (ton/ft^2)
Natural	Unsoaked	1.08
	Soaked	0.86
C4NP4	Unsoaked	2.2
	Soaked	5.78
C4NP8	Unsoaked	1.8
	Soaked	5.20
C4NP12	Unsoaked	2.31
	Soaked	3.92

DISCUSSION AND CONCLUSION

In this study, the effects of cement and natural pozzolan mixture on two different soils in terms of shear strength parameters and California Bearing Ratio (CBR) are studied. Firstly physical properties tests are carried out to identify and classify two different types of soil. According to test results, soil A is clayey sand in SC group and soil B is fat clay with sand in CH group. In order to obtain the optimum cement content on the basic of maximum dry density, the studied soils are mixed with 2%, 4%, 6% cement. The various percentages of cement and natural pozzolan mixture are used for stabilization of studied soils. Atterberg limit test, compaction test, triaxial shear (UU) test and CBR test are performed by adding various cement and natural pozzolan mixture to the studied soils. And then, the bearing capacities of subgrade of natural soil and cement-natural pozzolan treated studied soils are predicted depend upon the California Bearing Ratio test.

From the various soil test results, the following conclusions can be drawn.

1. By stabilizing the soils with cement and natural pozzolan mixture, PI values decrease 1.3 times and 3.6 times of natural soil for soil A and soil B respectively.
2. The maximum value of dry density for soil A is 124.2 lb/ft^3 at 2% cement and 4% natural pozzolan mixture. For soil B, the maximum value of dry density is 105.3 lb/ft^3 at 4% cement and 4% natural pozzolan mixture. The moisture content increases with an increase of cement content for all natural pozzolan content.
3. The increase in cohesion value of optimum cement–natural pozzolan stabilized soil A is 1.55 times greater and soil B is 1.5 times greater than that of natural soil. The increase in friction angle of optimum cement-natural pozzolan treated soil A is 1.54 times greater and soil B is ten times greater than that of natural soil.
4. From the test results, the soaked and unsoaked CBR values of optimum cement-natural pozzolan stabilized soil A is 8 times and 7 times greater than that of natural soil respectively. For soil B, the soaked and unsoaked CBR values are 3.8 times greater and 22 times greater than that of natural soil respectively.
5. From the test results, soil A is stabilized with cement and natural pozzolan mixture can be used as base in any (wet and dry) weather conditions. It can be seen that soil B treated with cement and natural pozzolan mixture can be used as sub-base in any (wet and dry) weather conditions.
6. From the calculation results, the highest bearing value is 2% cement and 12% natural pozzolan treated with soil A at both in soaked and unsoaked conditions. It is about 3.81 times and 3.85 times greater than that of natural soil in unsoaked and soaked conditions respectively.
7. For soil B, 4% cement and 4% natural pozzolan (NP) mixture with soil B is the highest bearing capacity at soaked condition and it is about 6.72 times greater than that of natural soil. In unsoaked condition, maximum bearing value of cement and NP mixture treated soil B is 4% cement and 12% NP. It is about 2.14 times greater than the bearing value of natural soil.
8. In this stabilization with cement and natural pozzolan of soil B is more effective than that of soil A.

Acknowledgement

Firstly, the author wishes to express her deep gratitude to his Excellency Union Minister Dr. Myo Thein Gyi, Ministry of Education, for opening the Special Intensive Course Leading to Master of Engineering at Pyay Technological University. The author would also like to thank Dr. Myint Soe, Rector of Pyay Technological University for his motivation, supports and guidance. The author would like to express her heartfelt gratitude to her supervisor Daw Phyu Phyu Lwin, Lecturer and Head of Civil Engineering Department of Pyay Technological University, for her kind advice, permission and supervision. The author would like to thank Daw Khin Thida and her staff members of Soil, Concrete Laboratory and Irrigation Construction Quality Control, Chaung Woon, Patheingyi, for their kind help during the study of this paper.

References

[1] Braja M. Das.: Principle of Geotechnical Engineering, Fourth Edition. Boston. U.S.A: PWS Publishing Company (1998).

[2] Joseph E. Bowels. “Engineering Properties of Soils and Their Measurement”. Second Edition.U.S.A:MC Graw-Hill.Inc, (1978).

[3] Robert W. Day: Foundation Engineering Handbook, (2006).

[4] Sivapullaiah,P.V., Sitharam, T.G. and Rao,K.S.Subba.: Modified Free Swell Index For Clays, Geotechnical Testing Journal, GTJODJ,Vol 10, No 2 (June 1987) pp 80-85.

[5] Murthy V.N.S.: Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering, Marcel Dekker, Inc; New York, (2003).

[6] Braja M.Das,:Principal of Geotechnical Engineering,Fifth Edition. California State University, Sacramento, PWS Publishing Company (2002)

[7] J. Paul. Guyer. P.E., R.A.: Introduction to Soil Stabilization in Pavements (2011).

[8] W. Colwill, Department for International Development of UK and Philippines:Design of Stabilized Sub- base for Heavily Traffied Roads(2002)

[9] Croney, D And Croney, P.: The Design and Performance of RoadPavements, 3rd Edition, Published by McGraw-Hill, UK, (1998).

[10] R.Gary Hicks, Professor Emeritus: Alaska Soil Stabilization Design Guide, Oregon State University, (2002).

[11] Oscar E. Manz.: Investigation of Pozzolanic Properties of the Cretaceous Volcanic Ash Deposit near Linton, North Dakota, (1961).

[12] Habiba Afrin, 'A Review on Different Types of Soil Stabilization Techniques', Internal Journal of Transportation Engineering and Technology, Rajshahi, Bangladesh,(2017)

[13] Ingles, O.G & J.B Metcalf., Soil Stabilization Principles and Practice, published by Butterworth & Co. Ltd., (1972).

[14] Magdi M. E. Zumrawi: "Predicting Bearing Strength Characteristics from Soil Index Properties, International Journal of Civil Engineering and Technology (IJCIET), Volume 7,Issue 2, March-April (2016), pp 266-277