Soil Stabilization using Phosphorus Pentoxide

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Abstract- *The search for efficient soil stabilizers to overcome the issues caused by the expansive soils is the main concern for the geotechnical engineers. This demand for soil stabilizing agents led to the research work which presented phosphorus pentoxide to be the one. This chemical stabilizing agent is added to the expansive soil in various proportions i.e. 0%, 5%, 10% and 15%. The strength parameters of the soil were found by conducting experiments such as Standard proctor test and unconfined compressive strength test. The soil properties were found by specific gravity test and Atterberg limits.*

Key Words: **Soil stabilization, Phosphorus pentoxide, Standard proctor test, unconfined compressive strength, Atterberg limits.**

1. INTRODUCTION

Soil stabilization is the process through which the physical properties of the soil was changed so that the shear strength of the soil is increased and the shrink or swell of the soil is controlled. This improvement in the soil properties increases the load bearing capacity of the sub grade to support pavements and foundations. Identifying the soil characteristics and improving the properties are done before the design phase, which determines the nature of the structure that is to be constructed. Thus, geotechnical study is inevitable for the construction industry.

The soil that is present in the earth's surface varies from place to place each having distinct properties. The soil must possess certain properties to safely carry the foundation or pavement, which not all soil can have. Thus, stabilizing the soil becomes unavoidable. There are several methods to improve the soil characteristics such as Physical methods, Chemical methods, Mechanical methods, etc. Depending upon the soil properties and the nature of construction suitable technique can be adopted.

Clayey soils are generally categorized as expansive soils, this type of soil is known to cause critical damage to the structures resting on them. This is due to poor properties of the soil and cannot withstand heavy loads from the structure resting on it. These kinds of soils expand and contract depending upon the temperature of the region. This volumetric change occur in the expansive soil is due to the presence of excessive water content in it. Thus, suitable method of stabilizing the soil should be adopted to prevent the volumetric change in the soil.

Phosphorus pentoxide is a dehydrating agent that absorbs water from the soil preventing it from volumetric change. When phosphorus pentoxide reacts with the water it produces phosphoric acid with liberation of excess heat. It is an exothermic reaction. This phosphoric acid acts as a binder to the soil particles thus improving its strength.

In this study, soil stabilization using phosphorus pentoxide was analysed.

2. MATERIALS AND METHODS

Chemical method of stabilizing the soil can be adopted to prevent the volumetric expansion of soil. There are several chemicals that can be used to stabilize the soil such as Lime, Sodium hydroxide, Aluminium oxide, Phosphorus pentoxide etc. Basically, all these chemical agents are dehydrating agents that remove the excess water present in the soil, thus preventing the expansive nature of the soil. In this study Phosphorus pentoxide is added in different proportions to the soil to stabilize the soil. Phosphorus pentoxide is a white colored sticky powder form which is highly reactive with water and clay particles in the soil. It improves the index properties, dry density and optimum moisture content of the soil.

Table-1: Physical properties of Phosphorus pentoxide

Properties	Values
Color	White yellow crystalline powder
Specific Gravity	2.72

3. EXPERIMENTAL WORK

Clay is finely grained natural rock or soil material that combines one or more clay materials with possible traces of quartz, metal oxides and organic matter. Clays are plastic due to its particle size, geometry and water content that becomes hard, brittle and non-plastic upon drying. For this research the soil sample was collected from Ondipudur region in Tamilnadu, India. To determine the soil characteristics of the collected samples basic tests like free swell index, specific gravity and Atterberg limits are carried out.

Table-2: Free Swell Index Value

Sample	V_d	V_k	Free Swell Value (%)= $((V_d-V_k)/V_k)x100$
Clay	14	10	40

Table-3: As per IS:2720(Part XL)-1997

Free Swell Index	Degree of expansiveness
<20	Low
20-25	Moderate
35-50	High
>50	Very high

From the free swell index test we can infer that the soil sample obtained has high degree of expansiveness.

Table-4: Specific gravity of Clay soil

Empty weight of pycnometer(W_1) (g)	Weight of pycnometer+ Soil(W_2) (g)	Weight of pycnometer+Soil+Water(W_3) (g)	Weight of pycnometer + Water (W_4) (g)
626	906	1594	1418

Specific gravity (G) = $(W_2-W_3)/((W_4-W_1)-(W_3-W_2))$
G = 2.7

Table-5: Liquid limit value

No of Blows	Water Content (%)
38	55
25	58
19	61
9	64

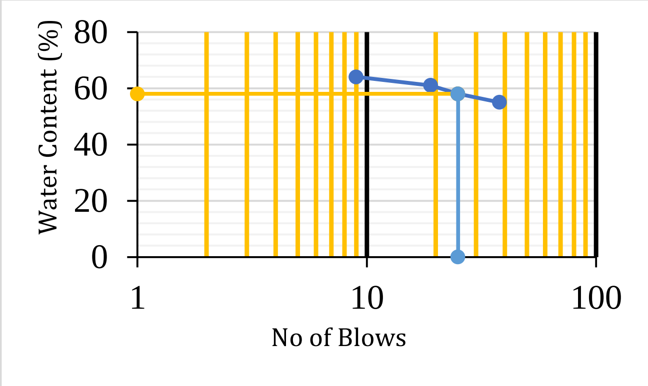

Fig-1: Liquid limit of clay soil

From graph, Liquid limit (W_L) = 58%

Table-6: Plastic limit value

Empty weight of can & lid (W_1) (g)	Wt. of can & lid + wet soil(W_2) (g)	Wt. of can & lid + dry soil (W_3) (g)	Plastic limit $((W_2-W_3)/(W_3-W_1))x100$ (%)
18	40	34	37.5

Plastic limit (W_P) = 37.5%

Plasticity Index (I_P) = W_L-W_P

= 58-37 = 20.5

Table-7: Shrinkage limit value

Description	Value
Empty wt. of shrinkage dish(W_1) (g)	40
Wt. of shrinkage dish + wet soil pat (W_2) (g)	78
Wt. of shrinkage dish + dry soil pat (W_3) (g)	64
Wt. of dry soil pat W_d = (W_3-W_1) (g)	24
Moisture content of soil (%)= $((W_2-W_3)/(W_3-W_1))x100$	58.3
Wt. of mercury filling the mercury dish (W_{m1}) (g)	294
Volume of wet soil pat, V= $W_{m1}/13.6$ (cc)	21.61
Wt. of mercury displaced in the shrinkage dish (W_{m2}) (g)	140
Volume of wet soil pat V_d= $W_{m2}/13.6$ (cc)	11.02

Shrinkage limit (W_s) = W- $(((V-V_d)/W_d)x100)$
= 58.3 - 47.2
= 11%

4. OBSERVATIONS AND RESULTS

Proctor compaction test is done on the soil for various mix proportions of phosphorus pentoxide to determine the optimum moisture content (OMC) and maximum dry density (MDD) of the soil.

Diameter of the mould (D) = 10cm

Volume of the mould (V) = 942cm^3

Height of the mould (h) = 12cm

Weight of the mould (M_1) = 4.674kg

Table-8: Proctor compaction value (0%)

Water content (W) %	Weight of soil and base plate (M_2)	Weight of soil $M = M_2 - M_1$	Bulk density of soil $\gamma = \frac{M}{V}$ x10^{-3}	Dry density $\gamma d = \gamma/(1+W)$ x10^{-3}
14	6.438	1.764	1.87	1.63
16	6.466	1.792	1.90	1.64
18	6.618	1.944	2.06	1.74
20	6.616	1.942	2.06	1.71
22	6.600	1.926	2.04	1.67
24	6.594	1.920	2.03	1.63

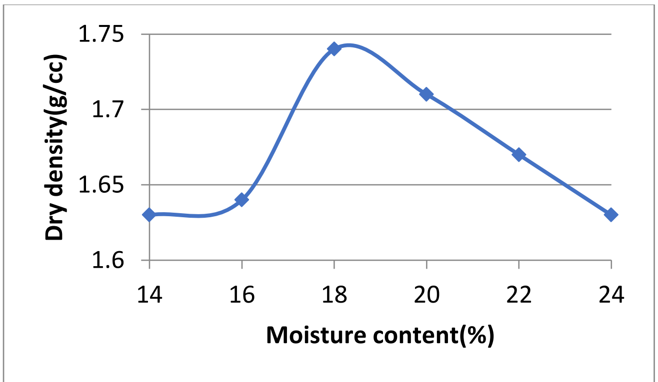

Fig-2: Compaction curve for 0%

From the graph, OMC = 18.3% and MDD = 1.74 g/cc

Table-9: Proctor compaction value (5%)

Water content (W) %	Weight of soil and base plate (M_2)	Weight of soil $M = M_2 - M_1$	Bulk density of soil $\gamma = \frac{M}{V}$ x10^{-3}	Dry density $\gamma d = \gamma/(1+W)$ x10^{-3}
14	6.488	1.814	1.93	1.69
16	6.536	1.862	1.98	1.71
18	6.708	2.034	2.16	1.83
20	6.706	2.032	2.16	1.8
22	6.670	1.996	2.12	1.74
24	6.644	1.970	2.09	1.69

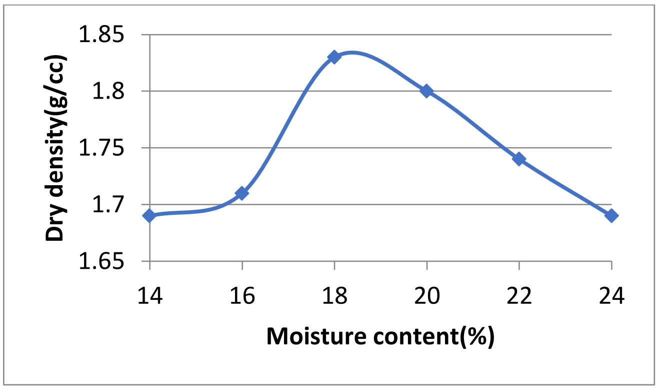

Fig-3: Compaction curve for 5%

From the graph, OMC = 17.9% and MDD = 1.83 g/cc

Table-10: Proctor compaction value (10%)

Water content (W) %	Weight of soil and base plate (M_2)	Weight of soil $M = M_2 - M_1$	Bulk density of soil $\gamma = \frac{M}{V}$ x10^{-3}	Dry density $\gamma d = \gamma/(1+W)$ x10^{-3}
14	6.578	1.904	2.02	1.77
16	6.646	1.972	2.09	1.80
18	6.838	2.164	2.30	1.95
20	6.836	2.162	2.29	1.91
22	6.780	2.106	2.24	1.84
24	6.734	2.060	2.19	1.77

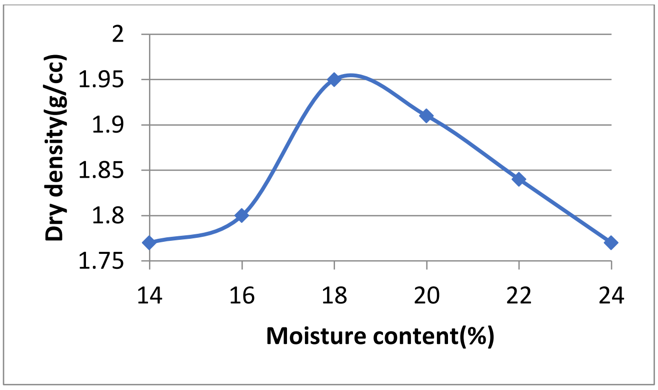

Fig-4: Compaction curve for 10%

From the graph, OMC = 17.6% and MDD = 1.95 g/cc

Table-11: Proctor compaction value (15%)

Water content (W) %	Weight of soil and base plate (M_2)	Weight of soil $M = M_2 - M_1$	Bulk density of soil $\gamma = \frac{M}{V}$ x10^{-3}	Dry density $\gamma d = \gamma/(1+W)$ x10^{-3}
14	6.541	1.867	1.98	1.74
16	6.591	1.917	2.04	1.76
18	6.765	2.091	2.22	1.88
20	6.782	2.108	2.24	1.87
22	6.725	2.051	2.18	1.79
24	6.698	2.024	2.15	1.73

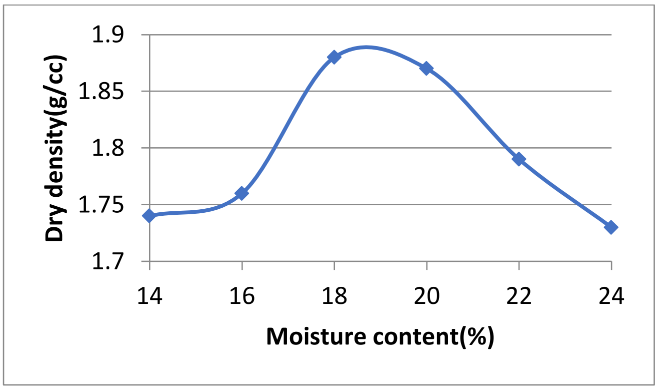

Fig-5: Compaction curve for 15%

From the graph, OMC = 18.2% and MDD = 1.88 g/cc

Unconfined compressive strength test is done for the soil samples of different mix proportions of phosphorus pentoxide. The soil samples are prepared by adding optimum water content obtained from the proctor test.

Table-12: Unconfined Compressive Strength Test (0%)

Dial guage reading (mm)	Change in length ΔL(mm)	Axial Strain ε =ΔL/L	Corrected area(mm^2) A $=\frac{Ao}{1-\varepsilon}$	Proving ring reading	Axial load P(N)	Stress σ = P/A (N/mm^2)
50	0.05	5 X 10^{-4}	1256.63	0.4	9.32	0.0074
100	0.1	1 X 10^{-3}	1257.25	0.8	18.64	0.015
150	0.15	1.5 X 10^{-3}	1257.88	1.2	27.96	0.022
200	0.2	2 X 10^{-3}	1258.52	2.6	60.58	0.048
250	0.25	2.5X 10^{-3}	1259.15	3.2	74.56	0.059
300	0.3	3X 10^{-3}	1259.78	3.8	88.54	0.070
350	0.35	3.5X 10^{-3}	1260.41	4.4	102.52	0.081
400	0.4	4 X 10^{-3}	1261.04	4.6	107.18	0.085
450	0.45	4.5X 10^{-3}	1261.67	5	116.5	0.092
500	0.5	5X 10^{-3}	1262.31	5.2	121.16	0.096
550	0.55	5.5X 10^{-3}	1262.95	5	116.5	0.092

Unconfined compressive strength (q_u) = 0.096 N/mm^2

Shear strength of soil = $q_u/2$ =0.048 N/mm^2

Table-13: Unconfined Compressive Strength Test (5%)

Dial guage reading (mm)	Change in length ΔL(mm)	Axial Strain ε =ΔL/L	Corrected area(mm^2) A $=\frac{Ao}{1-\varepsilon}$	Proving ring reading	Axial load P(N)	Stress σ = P/A (N/mm^2)
50	0.05	5 X 10^{-4}	1256.63	0.4	9.32	0.0074
100	0.1	1 X 10^{-3}	1257.25	0.8	18.64	0.012
150	0.15	1.5 X 10^{-3}	1257.88	1.6	37.28	0.029
200	0.2	2 X 10^{-3}	1258.52	2.8	65.24	0.052
250	0.25	2.5X 10^{-3}	1259.15	3.6	83.88	0.066
300	0.3	3X 10^{-3}	1259.78	4.6	107.18	0.085
350	0.35	3.5X 10^{-3}	1260.41	5.4	125.82	0.099
400	0.4	4 X 10^{-3}	1261.04	5.6	130.48	0.103

450	0.45	4.5X 10^{-3}	1261.67	6	139.8	0.111
500	0.5	5X 10^{-3}	1262.31	5.6	130.48	0.103

Unconfined compressive strength (q_u) = 0.111 N/mm²

Shear strength of soil = $q_u/2$ =0.055 N/mm²

Table-14: Unconfined Compressive Strength Test (10%)

Dial guage reading (mm)	Change in length ΔL(mm)	Axial Strain ε =ΔL/L	Corrected area(mm²) A $=\frac{Ao}{1-\varepsilon}$	Proving ring reading	Axial load P(N)	Stress σ = P/A (N/mm²)
50	0.05	5 X 10^{-4}	1256.63	0.4	9.32	0.0074
100	0.1	1 X 10^{-3}	1257.25	1.2	27.96	0.022
150	0.15	1.5 X 10^{-3}	1257.88	2.4	55.92	0.044
200	0.2	2 X 10^{-3}	1258.52	3.8	88.54	0.070
250	0.25	2.5X 10^{-3}	1259.15	4.8	111.84	0.088
300	0.3	3X 10^{-3}	1259.78	5.6	130.48	0.103
350	0.35	3.5X 10^{-3}	1260.41	6.8	158.44	0.126
400	0.4	4 X 10^{-3}	1261.04	7	163.10	0.129
450	0.45	4.5X 10^{-3}	1261.67	6.8	158.44	0.125

Unconfined compressive strength (q_u) = 0.129 N/mm²

Shear strength of soil = $q_u/2$ =0.064 N/mm²

Table-15: Unconfined Compressive Strength Test (15%)

Dial guage reading (mm)	Change in length ΔL(mm)	Axial Strain ε =ΔL/L	Corrected area(mm²) A $=\frac{Ao}{1-\varepsilon}$	Proving ring reading	Axial load P(N)	Stress σ = P/A (N/mm²)
50	0.05	5 X 10^{-4}	1256.63	0.4	9.32	0.0074
100	0.1	1 X 10^{-3}	1257.25	1	23.3	0.018
150	0.15	1.5 X 10^{-3}	1257.88	1.8	41.94	0.044
200	0.2	2 X 10^{-3}	1258.52	2.8	65.24	0.052
250	0.25	2.5X 10^{-3}	1259.15	4	93.2	0.074
300	0.3	3X 10^{-3}	1259.78	5	116.5	0.092
350	0.35	3.5X 10^{-3}	1260.41	5.4	125.82	0.095
400	0.4	4 X 10^{-3}	1261.04	5.2	121.16	0.093

Unconfined compressive strength (q_u) = 0.095 N/mm²

Shear strength of soil = $q_u/2$ =0.0475 N/mm²

5. CONCLUSIONS

1)In this research work Phosphorus pentoxide was used to stabilize the expansive soil resulting in improvement of geotechnical properties of the soil.

2)From the proctor compaction test, the optimum moisture content (OMC) value decreases with increase in percentages of Phosphorus pentoxide. The maximum dry density (MDD) value increases with increase in percentages of Phosphorus pentoxide.

3)The addition of Phosphorus pentoxide with the soil resulted in the improvement on UCC test. The strength increases with increase in percentages of Phosphorus pentoxide from 0% to 10% and then its strength decreases for 15%.

4)The UCC value for virgin clay and 10% chemical added clay were 0.096 N/mm² and 0.129 N/mm² respectively. Hence, we can conclude that 10% of phosphorus pentoxide is the optimum additive percentage in the soil.

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