IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

SOILSTABILIZATION AND MODIFICATION USING WASTE PAPER SLUDGE

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***Abstract*—Soil strength development involves the process of improving geotechnical properties of soil. There are many of industries growing in many countries like in India, in which industrial waste become a serious problems. In those industries paper mill industry is one of them, which produce thousands of tones waste material every year and year. Utilization of this waste material in required civil engineering area can be proved a good additive in construction. Waste Paper Sludge is a lime sludge wastage material come from Paper Industry generally dumped into sites around the Industries. 2 %, 4 %, 6 %, 8 % and 10 % Waste Paper Sludge added to the soil and conducted test for analysis of strength properties of soil. Laboratory experiments results showed that 6 % is the optimum percentage of Waste Paper Sludge (WPS) which is mixed in the soil for obtained higher strength. In civil engineering construction like Railway lines, Highway Network, Airport Runways etc are required a good strength of soil embankment, where Waste Paper Sludge (WPS) become a good additive for improving, stabilization and strength of soil.**

***Keywords*—soil stabilization; waste paper sludge; waste material; CBR; liquid limit; direct shear test**

I. INTRODUCTION

In Civil Engineering Construction like Railway lines, Highway Network, Airport Runways etc are required on Soil Embankment for construction. There are various processes like chemical, mechanical, biological or combined method in order to improve soil properties such as compressibility, strength, permeability and durability. Industrialization and urbanization is a major area of every country which is growing up in each year. Industrialization is one of the areas of each country in which numbers of industries are increasing year by year. These industries manufacture many items and also produce thousands of tones waste material. Paper mill Industries is one of them which create waste material every year.

Urbanization is the required for the growth of country resulting developing the lives of its country people. Civil construction is also a part of urbanization. Sometimes site engineers faces the problems in the field due to poor the strength of soil. Conventionally different materials like cement, lime and fiber etc are used to mix with soil for improving the strength of soil. These materials increase the cost of construction, results an uneconomical construction. In many industries waste materials are available which is not recycled yet for their utilizing purpose. Paper mill industries are one of them in which Waste Paper Sludge (WPS) is a waste materials dumped around the industry premise. This waste material also covers a large area to landfill. When this waste material dried in presence of sun light creates dust which leads to the air pollution in nearby areas which also affects human health.

II. FACTORS AFFECTING THE STRENGTH OF STABILIZED SOIL

A. Organic matter

In many cases, the top layers of most soil constitute large amount of organic matters. However, in well drained soils organic matter may extend to a depth of 1.5 m. Soil organic matters react with hydration product e.g. calcium hydroxide ($Ca(OH)2$) resulting into low pH value. The resulting low pH value may retard the 10 hydration process and affect the hardening of stabilized soils making it difficult or impossible to compact.

B. Sulphates

The use of calcium-based stabilizer in sulphate-rich soils causes the stabilized sulphate rich soil in the presence of excess moisture to react and form calcium sulphoaluminate (ettringite) and or thamausite, the product which occupy a greater volume than the combined volume of reactants. However, excess water to one initially present during the time of mixing may be required to dissolve sulphate in order to allow the reaction to proceed.

C. Moisture content

In stabilized soils, enough moisture content is essential not only for hydration process to proceed but also for efficient compaction. Fully hydrated cement takes up about 20% of its own weight of water from the surrounding on other hand, Quicklime (CaO) takes up about 32% of its own weight of water from the surrounding. Insufficient moisture content will cause binders to 12 compete with soils in order to gain these amounts of moisture. For soils with great soil water affinity (such as clay, peat and organic soils), the hydration process may be retarded due to insufficient moisture content, which will ultimately affect the final strength.

D. FREEZE THAW AND DRY-WET EFFECT

Stabilized soils cannot withstand freeze-thaw cycles. Therefore, in the field, it may be necessary to protect the stabilized soils against frost damage. Shrinkage forces in stabilized soil will depend on the chemical reactions of the binder. Cement stabilized soil are susceptible to frequent dry-wet cycles due to diurnal changes in temperature which may give rise to stresses within a stabilized soil and, therefore, should be protected from such effects.

III. COMPONENTS OF SOIL STABILIZATION

Soil stabilization is the process of improving the engineering properties of weak soil and thus making it more stable. The chief properties of a soil with which the construction engineer is concerned are: volume stability strength, permeability, and durability. Soil stabilization involves the use of stabilizing agents (binder materials) in weak soils to improve its geotechnical properties such as compressibility, strength permeability and durability. The components of stabilization technology include soils and or soil minerals and stabilizing agent or binders.

A. SOIL

Most of stabilization has to be undertaken in soft soils (silty, clayey peat or organic soils) in order to achieve desirable engineering properties. A clay soil compared to others has a large surface area due to flat and elongated particle shapes.

B. WASTE PAPER SLUDGE

Waste Paper Sludge (WPS) is a waste material collected from the Paper Industry. WPS becomes a new innovation material that can be used as material for soil stabilizing agent. Recycling and reuse of paper sludge is a topic of international interest in the past few decade.
The paper sludge for the study was collected from a recycled paper manufacturing company. The sludge for the soil stabilization behaves a clay-like material consisting of short fibers, ink and other impurities. During the paper recycling process, waste papers were collected and de-inked prior to recovery of the fiber. The sludge in the study will be the fiber sludge generated from the deinking process, which contains fibers too short to be converted to a finished paper product. The sludge will be partially dewatered before discharge and the texture will soft and limp. Since the plant operated at 24 hours a day, 7 days a week, the sludge generates continuously throughout the operating year. Freshly collected sludge samples will be essentially odorless and there will not be any distinct odors. It consists of unusable short fibers, inks and dyes, clay, glues and other residue, along with any chemicals used in the recovery process. Fig. shows waste paper sludge at dried condition.

IV. METHODOLGY

The basic methodology of this project is the collection, and testing of soil. This is done in order to determine the quality of soil and its strength i.e. its bearing capacity.
Additive of WPSA is a finely waste product produced from the incinerated waste paper. In ASTM C618, this WPSA samples are categorized as Type-C fly ash due to the high free lime (CaO) content (>20%) and possesses some cementitious and pozzolanic, resulting in the self-cementing characteristics. Several percentage of WPSA (4%, 8%, 12% and 16%) was used to stabilize the soft soil. Meanwhile the compactions methods are used in this study are standard proctor test and modified proctor test. The Atterberg limit properties testing involved the liquid limit testing, and plastic limit testing. This mixed sample is then tested at each proportions and the bearing capacity is determined.
Our main purpose is mainly to determine the proportion at which our bearing capacity obtained is maximum.

A. SIEVE ANALYSIS OF ORIGINAL SOIL SAMPLE

S. No.	OBSERVATIONS			CALCULATIONS		
	IS sieve	Size of opening(mm)	Mass of soil retained(g)	%age retained	Cumulative %age retained	%age finer
1.	4.75 mm	4.75	-	-	-	-
2.	2mm	2.00	28.2	14.1	14.1	85.9
3.	600µ	0.600	24.5	12.25	26.35	73.65
4.	425µ	0.425	17.9	8.95	35.3	64.7
5.	300µ	0.300	14.38	7.19	.49	57.51
6.	212µ	0.212	22.4	11.2	53.69	46.31
7.	150µ	0.150	35	17.5	71.19	28.81
8.	75µ	0.075	20.2	10.1	81.29	18.71
9.	Pan	-	37.4	18.71	100	-

Result:

1. According to above data the soil sample is classified as **silty sand (SM).**
2. Plasticity index of our observed sample is less than 4.

B. INDEX PROPERTIES OF SOIL SAMPLE

1. WATER CONTENT

S.No.	Sample No.	1	2	3
1	Weight of container with lid W1 gm	20.12	20.08	20
2	Weight of container with lid +wet soil W2 gm	44.12	44.11	46.10
3	Weight of container with lid +dry soil W3 gm	41.18	41.16	43.10
4	Water/Moisture content W = [(W2-W3)/(W3-W1)]/100	13.96	13.99	13.43

RESULT: Water content = (13.96+13.99+13.43)/3=13.79%

2. SPECIFIC GRAVITY

S. No.	Observation Number	1	2	3
1	Weight of density bottle (W1 g)	18.57	18.50	18.62
2	Weight of density bottle + dry soil (W2 g)	28.57	28.50	28.62
3	Weight of bottle + dry soil + water at temperature 250 C (W3 g)	90.88	90.20	91.20
4	Weight of bottle + water (W4 g) at temperature 250 C	84.74	84	84.83
	Specific gravity G at 250 C (W2- W1)/(W4-W1)-(W3- W1)	2.54	2.63	2.62
	Average specific gravity at 250 C	2.69		

RESULT: Specific gravity at 250C= 2.69

3. DRY DENSITY OF SOIL (CORE CUTTER METHOD)

S.no.	Description	Determination No. 1.	2.	3.
1	Internal dia. of core cutter in mm	100	100	100
2	Internal height of core cutter in mm	129.75	129.75	129.75
3	Volume of cutter in cc	1019.05	1019.05	1019.05
4	Weight of core cutter in g	1130	1130	1130
5	Weight of core cutter (W1) + soil (W2) in g	3120	3122	3119
6	Weight of soil (W2-W1) in g	1990	1992	1989
7	Bulk density of soil y=(W2- W1)/V	1.95	1.95	1.95
8	Moisture content (w) in %	17.75	17.76	17.73
9	Dry density of soil yd= $\frac{100\gamma}{100+w}$ g/cc	1.66	1.66	1.66
AVERAGE VALUE = 1.66g/cc				

4. PROPERTIES OF WASTE PAPER SLUDGE

1	Specific gravity	1.33
2	pH	7.04
3	Water content (%)	60-120
4	ø	13.50
5	C	0.17
6	Hydraulic conductivity (m/s)	1.1 x10-8

5. ATTERBERG'S LIMIT TEST

i. LIQUID LIMIT

➢ Testing on original sample

Mass of dry soil=200g Sample passing 425µ IS sieve

S. No.	OBSERVATIONS	SAMPLE 1	SAMPLE 2	SAMPLE 3
1.	No. of blows	34	16	6
2.	Container no.	19	21	15
3.	Weight of empty container (g)	12	15.5	14
4.	Wt. of container + wet soil(g)	43.68	40.42	35.508
5.	Wt. of container + dry soil(g)	41.78	37.92	32.25
6.	Mass of water (g)	1.9	2.5	3.25
7.	Mass of solid (g)	29.78	22.42	18.25
8.	Water content= (6/7)*100	6.38%	11.15%	17.8%

RESULT: Liquid limit at 25 no. of blows=7.6

➢ Testing on soil sample with 10% WPS

Mass of dry soil=200g Sample passing 425µ IS sieve

S. No.	OBSERVATIONS	SAMPLE 1	SAMPLE 2	SAMPLE 3
1.	No. of blows	13	23	35
2.	Container no.	10	25	19
3.	Weight of empty container (g)	12	9	13.5
4.	Wt. of container + wet soil(g)	37.6	35.39	55.31
5.	Wt. of container + dry soil(g)	34.76	33.64	54.32
6	Mass of water (g)	2.5	1.75	1
7.	Mass of solid (g)	22.76	24.64	40.81
8.	Water content= (6/7)*100	10.98	7.81	2.45

RESULT: Liquid limit at 25 no. of blows=4.25

ii. PLASTIC LIMIT

➢ Testing on original sample

Mass of dry soil=200g Sample passing 425µ IS sieve

S. No.	OBSERVATIONS	SAMPLE 1	SAMPLE 2	SAMPLE 3
1.	No. of blows	13	23	35
2.	Container no.	10	25	19
3.	Weight of empty container (g)	12	9	13.5
4.	Wt. of container + wet soil(g)	37.6	35.39	55.31
5.	Wt. of container + dry soil(g)	34.76	33.64	54.32
6.	Mass of water (g)	2.5	1.75	1
7.	Mass of solid (g)	22.76	24.64	40.81
8.	Water content= (6/7)*100	10.98	7.81	2.45

RESULT: Plastic limit = (10.985+7.81%+2.45%)/3 = 6.84%

➢ Testing on soil sample with 10% WPS

Mass of dry soil=200g Sample passing 425µ IS sieve

S. No.	OBSERVATIONS	SAMPLE 1	SAMPLE 2	SAMPLE 3
1.	Container no.	19	21	15
2.	Weight of empty container(g)	12	15.5	14
3.	Wt. of container + wet soil(g)	43.68	40.42	35.508
4.	Wt. of container + dry soil(g)	41.78	37.92	32.25
5.	Mass of water (g)	1.9	2.5	3.25
6.	Mass of solid (g)	29.78	22.42	18.25
7.	Water content= (5/6)*100	6.38%	11.15%	17.8%

RESULT: Plastic limit = (6.38%+11.15%+17.8%)/3=11.7%

6. C.B.R.(CALIFORNIA BEARING RATIO) TEST

a. TESTING DONE UNDER UNSOAKED CONDITION:

S. No.	PENETRATION (mm)	TEST LOAD (kN) NATIVE SOIL	TEST LOAD (kN) TREATED SOIL	STANDARD LOAD (KN)
1.	0	0	0	0
2	2.5	62.77	73.689	13.70
3	5	95.59	97.51	20.55
4	7.5	115.98	125.62	26.30
5	10	126.73	131.06	31.80
6	12.5	132.89	140.69	36.00

RESULT-:

FOR NATIVE SOIL FOR TREATED SOIL WITH 10%WPS

C.B.R (2.5 mm) = 4.58% C.B.R (2.5 mm) = 5.37%

C.B.R (5 mm) = 4.65% C.B.R (5 mm) = 4.74%

value of CBR = 4.58% at 2.5 mm Maximum value of CBR = 5.37% at 2.5 mm

b. TESTING DONE UNDER SOAKED CONDITION (3 DAYS CURING)

S. No.	PENETRATION (mm)	TEST LOAD (kN) NATIVE SOIL	TEST LOAD (kN) TREATED SOIL	STANDARD LOAD (KN)
1.	0	0	0	0
2	2.5	71.8	79	13.70
3	5	104	109	20.55
4	7.5	129	135	26.30
5	10	141	149	31.80
6	12.5	152	156	36.00

RESULT-:

FOR NATIVE SOIL FOR TREATED SOIL WITH 10%WPS

C.B.R (2.5 mm) = 5.24% C.B.R (2.5 mm) = 5.76%

C.B.R (5 mm) = 5.06% C.B.R (5 mm) = 5.30%

value of CBR = 5.24% at 2.5 mm Maximum value of CBR = 5.76% at 2.5 mm

c. TESTING DONE UNDER SOAKED CONDITION (7 DAYS CURING):

S. No.	PENETRATION (mm)	TEST LOAD (kN) NATIVE SOIL	TEST LOAD (kN) TREATED SOIL	STANDARD LOAD (KN)
1.	0	0	0	0
2	2.5	79	84.8	13.70
3	5	109	123	20.55
4	7.5	135	154	26.30
5	10	149	164	31.80
6	12.5	156	185	36.00

RESULT-:

FOR NATIVE SOIL FOR TREATED SOIL WITH 10%WPS

C.B.R (2.5 mm) = 5.76% C.B.R (2.5 mm) = 6.18%

C.B.R (5 mm) = 5.34% C.B.R (5 mm) = 5.98

value of CBR = 5.76% at 2.5 mm Maximum value of CBR = 6.18% at 2.5 mm

7. DIRECT SHEAR TEST

a. TESTING DONE ON ORIGINAL SAMPLE:

TEST N O.	NORMAL STRESS (Kg/cm2)	SHEAR STRESS AT FAILURE(Kg/cm2)	SHEAR DISCPLACEMENT AT FAILURE
1.	.5	.569	.4
2.	1.0	.897	.532
3.	1.5	1.2	.672

SHEAR STRENGTH PARAMETER-:

value of effective cohesion C= 0
Angle of shearing resistance = 310
Shear strength of soil = 0.90Kg/cm*2

b. TESTING DONE ON SOIL WITH 10% WPSA

TEST N O.	NORMAL STRESS (Kg/cm2)	SHEAR STRESS AT FAILURE(Kg/cm2)	SHEAR DISCPLACEMENT AT FAILURE
1.	.5	.569	.381
2.	1.0	.897	.493
3.	1.5	1.2	.583

SHEAR STRENGTH PARAMETER-:

value of effective cohesion C= 0
Angle of shearing resistance =31^0
Shear strength of soil =0.90Kg/cm*2

8. PROCTOR TEST

a. TESTING DONE ON ORIGINAL SAMPLE
Total mass of the sample = 2K Sample pass from 20mm and retained on 4.75mm

Cylinder diameter =100mm,
a. Height = 127.3
b. Volume V = 1000ml
Specific gravity of soil G = 2.67

S.No 1	OBSERVATION AND CALCULATION	DETERMINATION N0.		
	OBSERVATION	1	2	3
	Mass of empty mould + base plate(g)	3885.5	3885.5	3885.5
2	Mass of empty mould + base plate(g) + mass of compacted soil(g)	5676	5789.5	5720.5
3	mass of compacted soil(g) M=2-1	1790.5	1904	1835
4	Bulk density q= M/V(g/cc)	1.79	1.90	1.83
5	Water content 'w'(%)	5%	15%	16.8%
6	Dry density qd= q /(1+w) (g/cc)	1.70	1.652	1.58
7	Void ratio e=(Gqw/ qd)-1	0.57	1.32	0.63

CALCULATION-:

q = 1904/1000 =1.904 g/cc; w = 15%;
q d = 1.90/(1+0.15) = 1.652 g/cc; e = ((2.67*1)/1.652)-1 = 1.32
q d (at 100% saturation) = (2.67*1)/(1+(0.15*2.67) =3.32 g/cc

RESULT-:
From the above result
O.M.C =15%
Max. Dry density =3.32 g/cc

b. TESTING DONE ON SOIL WITH 2 % WPSA
Total mass of the sample = 2Kg , Sample pass from 20mm and retained on 4.75mm

Cylinder diameter = 100mm ,
a. Height = 127.3
b. Volume V = 1000ml
Specific gravity of soil G = 2.67

S.No	OBSERVATION AND CALCULATION	DETERMINATION N0.		
	OBSERVATION	1	2	3
1	Mass of empty mould + base plate(g)	3885.5	3885.5	3885.5
2	Mass of empty mould + base plate(g) + mass of compacted soil(g)	6132	6498	6711
3	mass of compacted soil(g) M=2-1	2246.5	2612.5	2825.5
4	Bulk density q = M/V(g/cc)	2.24	2.61	2.82
5	Water content 'w'(%)	6.1%	16.8%	10.5%
6	Dry density q d= q /(1+w) (g/cc)	2.11	2.36	2.43
7	Void ratio e=(G qw / qd)-1	0.255	0.122	0.090

CALCULATION-:

q = 2825.5/1000 =2.85g/cc; w = 10.5%;
q d = 2.85/(1+0.105 = 2.43g/cc; e = ((2.67*1)/1.814)-1 = .090
q d (at 100% saturation) = (2.67*1)/(1+(0.105*2.67) =3.86g/cc

RESULT-:
From the above result
O.M.C =10.5%
Max. Dry density =3.86g/cc

c. TESTING DONE ON SOIL WITH 6 % WPSA
Total mass of the sample = 2Kg , Sample pass from 20mm and retained on 4.75mm

Cylinder diameter = 100mm ,
a. Height = 127.3
b. Volume V = 1000ml

Specific gravity of soil G = 2.67

S.No	OBSERVATION AND CALCULATION	DETERMINATION N0.		
	OBSERVATION	1	2	3
1	Mass of empty mould + base plate(g)	3885.5	3885.5	3885.5
2	Mass of empty mould + base plate(g) + mass of compacted soil(g)	5728.5	5946	5831.5
3	mass of compacted soil(g) M=2-1	1843	2060.5	1946
4	Bulk density q = M/V(g/cc)	1.84	2.06	1.94
5	Water content'w'(%)	5%	12%	9%
6	Dry density q d= q /(1+w) (g/cc)	1.755	1.855	1.785
7	Void ratio e=(G qw/q d)-1	0.52	.44	0.495

CALCULATION-:

q = 2060.5/1000 =2.06 g/cc; w = 12%;
q d = 2.014/(1+0.12) = 1.855g/cc; e = ((2.67*1)/1.814)-1 = .44
q d (at 100% saturation) = (2.67*1)/(1+(0.12*2.67) =3.515g/cc

RESULT-;
From the above result
O.M.C =12%
Max. Dry density =3.55g/cc

V. RESULTS AND DISCUSSION

- Standard proctor tests were conducted on 2 % , 6 % and 10 % Waste Paper Sludge (WPS) mixed to the soil Abbreviations and Acronyms
- Optimum moisture content increased and maximum dry density decreased of soil with addition of Waste Paper Sludge (WPS) up to 10 %.
- The relationship graph between dry density and water content plot for different percentage of Waste Paper Sludge (WPS) mixed to soil.

VI. CONCLUSION

- Liquidity of treated soil sample decreases with increasing the proportion of WPS and at 10% WPS liquidity of treated soil reduces up to 40% of original soil sample.
- Decrease in the LL indicates improvement in soil.
- Plasticity of treated soil sample increases with increasing the proportion of WPS and at 10% WPS plasticity of treated soil reduces up to 41.5% of original soil sample.
- Increase in the PL indicates improvement in soil.
- It can be seen that, the CBR values were improved for clay stabilized with addition of 10% WPSA for soaked and unsoaked condition compared to the control (unstabilized clay).
- The CBR result shows, the soaked condition result was increased about 1.5 times unstabilized clay soil and unsoaked condition shows increment of 3.6 times unstabilized clay soils. Hence, 10% of WPSA additives can potentially and effectively improve clay soil subgrade from poor to good conditions.
- This happened because pozzolanic reaction produced calcium silicate hydrates (CSH) and calcium aluminate hydrates (CAH) .
- Shear strength of treated soil sample increases with increasing the proportion of WPS and at 10% WPS shear strength of treated soil increases up to 7.33% of original soil sample.

VII. FUTURE SCOPE

- Stabilization using waste paper sludge can be used as to maintain the stability of foundation where the soil sandy-clayey.
- Stabilization of high swelling soil by using waste paper sludge at lower cost and eco-friendly method
- WPS can be also used for square foundation instead of pile foundation for sandy-clayey soil..
- The scope for landfill spreading is limited. Usage of paper increased to a great extent now days, results in large production of waste paper sludge (WPS). A large percentage of WPS produced are used for land filling and it run out of the storage space. There is therefore a growing need to find alternative uses of Waste Paper Sludge.
- This study explored the possibility of utilizing WPS for ground improvement schemes in geotechnical engineering applications.
- **Paper mill sludge** is a major **environmental problem** for the paper industry. The material is a by-product of the de-inking and repulping of paper. The total quantity of **paper mill sludge produced in annually is large quantity.** The main recycling and disposal routes for paper sludge are land-spreading as agricultural fertilizer, incineration in plants at the paper mill, producing paper sludge ash or disposal to landfill.
- Paper Sludge has high percentage of lime hence it is a very good stabilizing agent.

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