# Shear Strength of Soil in Polluted Geo-Environment

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***ABSTRACT* - The present study is conducted to investigate the effects of industrial liquid waste on the environment. The major categories of such waste are Paper Mill Waste, Chemical Plant Waste and Soft Drinks Bottling Plant Waste. The magnitude of the shear stress that a soil can sustain is called shear strength. The bonding or cementation of soil occurs due to the interlocking of particles.**

**The paper examines the effects of various chemicals in combination on the index properties and shear-strength behavior of bentonite. Bentonite is an absorbent aluminium phyllosilicate clay consisting mostly of montmorillonite. The property of swelling on contact with water makes sodium bentonite useful as a sealant, since it provides a self-sealing, low-permeability barrier.**

**The paper further studies the effect of paper mill waste and how it reduces the liquid limit of bentonite. Soft drinks bottling plant waste and chemical plant waste increase the liquid limit of bentonite and also increases phosphates and ammonical nitrogen. The concentration in pore fluid increases the liquid limit of bentonite. However, interaction with sulphates and fluorides reduces the liquid limit of bentonite.**

**Test results indicate that the increase in the shear strength of bentonite increases concentration of phosphates and sulphates. Results also observed that the shear strength of non-swelling soil is reduced on treatment with paper mill waste, dairy waste and pharmaceutical waste.**

## I. INTRODUCTION

The socio-economic progress of a country depends upon its industrial growth. The amount of industrial activity is an indicator of well-being of a nation but at the same time industrial activities generate large amount of solid and liquid wastes. Indiscriminate disposal of industrial wastes is a source of ground contamination. The behavior of soil-rock is modified in the presence of pollutants which find their way into the ground because of continued disposal of large quantities of wastes on to land. There has been a growing amongst geotechnical and environmental engineers about the detrimental effects to strength, deformation and seepage behavior of soils subjected to contaminated water percolating through it and the effect on the quality of fresh water in near by areas for human consumption.

So far most of the work done concentrated in studying the soil behavior in presence of effluents and individual chemicals. Effluent of any kind contains a number of chemicals in it. Moreover if we study the soil behavior when treated with effluent it will give only an idea about soil behavior when contaminated. But it will not give any idea regarding the effect of various chemicals present in the effluent on soil behavior. An individual chemical shows entirely different properties than when it is present in combination with some other chemicals. So it is very much necessary to study the soil behavior when treated with a particular set of chemicals, in combination in varying proportions. This sort of tests might be very useful in drawing certain guide lines regarding the chemical composition and disposal techniques of effluents.

## II. FUNDAMENTALS OF SOIL BEHAVIOUR

Two structural units are involved in the atomic lattice in most of the clay minerals. One unit consists of two sheets of closely packed oxygen or hydroxyls in which aluminium, iron, or magnesium atoms are embedded in octahedral coordinations so that they are equidistant from six oxygen or hydroxyls. When magnesium is present, all the positions are filled to balance the structure, which is the Gibbsite structure and has the formula $Al_2\,(OH)_6$. When the magnesium is present all the positions are filled to balance the structure which is the brucite structure and has the formula Mg $(OH)_6$ . The normal 0 to 0 distance is 2.60 $A^0$, and common OH-OH distance is $2.94A^0$, and the space available for ion in octahedral coordination is about $0.61A^0$. The thickness of the unit is $5.05A^0$ in clay mineral structures.

The second unit is built of silica tetrahedrons. In each tetrahedron a silica atom is equidistant from four oxygen, or hydroxyls if needed to balance the structure arranged in the form of tetrahedron with a silica atom at the centre. The silica tetrahedron groups are arranged to form a hexagonal network, which is separated indefinitely to form a sheet of composition $Si_4O_6(OH)_4$. The tetrahedrons are arranged so that the tips of all of

them point in the same direction, and the bases of all tetrahedrons are in the same plane. The open hexagonal network can be considered to be composed of three strings of oxygen atom intersecting at the angles of $120^0$.

Typical values of consistency limits for cohesive soil :

| Mineral | Exchangeable Ion | Liquid limit (%) | Plastic limit (%) | Plasticity index (%) | Shrinkage limit (%) |
|---|---|---|---|---|---|
| Montmorillonite | Na | 710 | 54 | 656 | 9.9 |
| | K | 660 | 98 | 562 | 9.3 |
| | Ca | 510 | 81 | 429 | 10.5 |
| | Mg | 410 | 60 | 350 | 14.7 |
| | Fe | 290 | 75 | 215 | 10.3 |

## III. METHODOLOGY OF TREATMENT OF SOILS WITH THE EFFLUENTS

Effluents were collected in 50 liters plastic containers from their point of disposal. The effluents were brought to laboratory and immediately mixed with bentonite in a soil-solution ratio of 1:10.The soils were treated with the effluents for 15 days with regular mixing. After 15 days the supernatant liquid was discarded. The treated soils were air dried, pulverized and passed through 425 micron sieve. The effective stress concept can be stated as

$$\sigma^1 = \sigma - u \qquad (1)$$

where $\sigma^1$ = Effective stress,

$\sigma$ = Applied external pressure,

u = Pore water pressure.

The concept as given in equation (1) tacitly assumes that no other forces except the external applied pressure and the hydrostatic pressure u exist with in the particulate system. $\sigma^1$ is the contact stress at mineral to mineral contact zone. Attractive and repulsive forces of an electrical nature exist between clay particles. The repulsive forces between clay particles are primarily attributed to an interaction between electrical double layers. The principle contributions to the attractive and repulsive forces mainly depends on the interparticle separation, clay mineral type, exchangeable cation type and pore fluid characteristics. Lambe (1960) introduced an equation relating the total external load to the internal stresses in the particulate soil system. His generalized equation is

$$\sigma = \bar{\sigma}\mathrm{am} + \bar{u} + \mathrm{R} - A$$

Where

$\sigma$ = Total stress

$\bar{\sigma}$ = Mineral to mineral contact stress

am = Fraction of the total interparticle contact area

A = Total interparticle attraction divided by interparticle area

R = Total interparticle repulsion divided by interparticle area

$\therefore$ Effective stress, $\sigma^1 = \sigma - u = \bar{\sigma}\mathrm{am} \mp R - A$

From this equation it is seen that the effective stress increases with repulsive forces and decreases with attractive forces. This does not agree with the physical behavior. Sridharan (1968) rewrote Lambe's equation in the following manner.

$$C = \sigma - u_a - u_w - R + A$$

Where

C = Effective contact stress

$\sigma$ = Externally applied pressure

$u_w$ = Effective pore water pressure

$u_a$ = Effective pore air pressure

The above equation has been formulated with the reasoning that the repulsive forces tend to separate the clay particles away from each other in the same way as the positive pore water pressure does and the attractive forces tend to bring the clay particles closer together in the same way as the external normal force does. The primary force which is responsible for repulsion between two clay particles is due to the interaction of diffuse double layers. This repulsive force is proportional to the dielectric constant of the pore medium. The attractive forces vary inversely and the repulsive forces vary directly with the dielectric constant of the pore medium. Both these forces vary inversely with the distance between the particles.

## IV. RESULTS AND DISCUSSIONS

### RESULTS :

TABLE 1 : LIQUID LIMITS

| Description | Liquid limit (%) |
|---|---|

| | |
|---|---|
| Distilled water (Natural Bentonite) | 115 |
| Paper mill waste treated Bentonite | 67 |
| Soft drinks bottling plant waste treated Bentonite | 157 |
| Chemical plant waste treated Bentonite | 177 |
| Fluid 1 | 69 |
| Fluid 2 | 62 |
| Fluid 3 | 59 |
| Fluid 4 | 55 |
| Fluid 5 | 57 |

TABLE 2 :PLASTIC LIMITS

| Description | Liquid limit (%) |
|---|---|
| Distilled water (Natural Bentonite) | 22 |
| Paper mill waste treated Bentonite | 31 |
| Soft drinks bottling plant waste treated Bentonite | 23 |
| Chemical plant waste treated Bentonite | 18 |
| Fluid 1 | 20 |
| Fluid 2 | 20 |
| Fluid 3 | 21 |
| Fluid 4 | 21 |
| Fluid 5 | 32 |

Table 3 : COHESION AND ANGLE OF INTERNAL FRICTION

| Description | C (KPa) | Φ (Degrees) | Shear Strength (KPa) |
|---|---|---|---|
| Distilled water (Natural Bentonite) | 44 | 2 | 96 |
| Paper mill waste treated Bentonite | 30 | 1 | 64 |
| Soft drinks bottling plant waste treated Bentonite | 50 | 3 | 114 |
| Chemical plant waste treated Bentonite | 70 | 2 | 150 |
| Fluid 1 | 36 | 5 | 120 |
| Fluid 2 | 28 | 12 | 180 |

| | | | |
|---|---|---|---|
| Fluid 3 | 34 | 9 | 150 |
| Fluid 4 | 30 | 12 | 160 |
| Fluid 5 | 56 | 7 | 180 |

## V. DISCUSSIONS:

### *Liquid Limit:*

Table 1 presents the liquid limits of effluent treated and untreated Bentonite soil. Treatment with paper mill waste reduces the liquid limit of bentonite from 115% to 67%. When bentonite is treated with soft drinks bottling plant waste liquid limit is increased from 115% to 157%. When bentonite is treated with chemical plant waste liquid limit is increased from 115% to 147%.

Table 1 shows that liquid limit is decreased from 69% to 62%. When sulphate concentration is increased from 0 to 2000ppm (Fluid $F_1$ to $F_2$ ). Liquid limit decreased from 62% to 59% when concentration of phosphates is decreased from 1000ppm to 500ppm (Fluid $F_1$ to $F_2$). There is a decrease in liquid limit from 59% to 55% due to decreased concentration of ammonical nitrogen from 1000ppm to 500ppm (Fluid $F_3$ to $F_4$). Liquid limit slightly increased from 55% to 57% with decreased fluoride concentration from 50ppm to 10ppm (Fluid $F_4$ to $F_5$).In the present study the liquid limit behavior followed the above trend in all cases i.e. the three effluents, decreased concentration of sulphates, phosphate, fluorides and ammonical nitrogen.

Sulphate adsorption in presence of phosphates, fluorides and ammonical nitrogen may decrease diffused double layer thickness around bentonite particles due to higher electrolyte concentration. This result in decreased liquid limit.Fluoride adsorption in presence of sulphates, ammonical nitrogen and phosphates, may result in the same behavior as sulphates. However in the present study liquid limit is increased due to increased concentration of phosphates. Presumably sulphates and fluorides which are simultaneously present in the chemical solutions (fluid F2 and F3) along with phosphates override the influence of phosphates an cause an increase in the liquid limit of Bentonite. Ammonical nitrogen adsorption in presence of sulphates, fluorides and phosphates may result in the same behavior as phosphates.

### *Plastic Limit:*

From Table 2 it is evident that the plastic limit of Bentonite is increased from 22% to 31% when it is treated with paper mill waste. When bentonite is treated with soft drinks bottling plant waste plastic limit is slightly increased from 22% to 23%.The plastic limit is decreased from 22% to 18% when bentonite is treated with chemical plant waste. From Table 2 it can be seen that sulphates, phosphates, and ammonical nitrogen showed not much variation in the plastic limit behavior of Bentonite.

### *Shear Strength:*

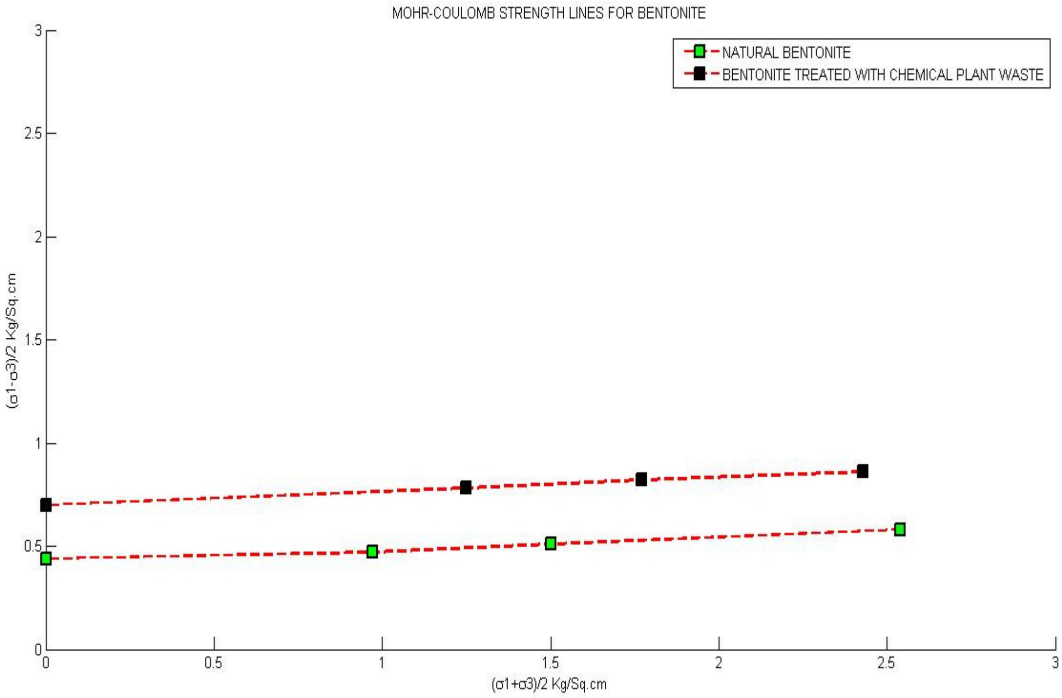
Table.3 presents cohesion, angle of internal friction and shear strength of effluents treated and untreated Bentonite soil. From Table.5 it is evident that treatment with paper mill waste reduces the cohesion of bentonite from 44KPa to 30KPa. When treated with soft drinks bottling plant waste, cohesion increased from 44KPa to 50KPa.Treatment with chemical plant waste increases cohesion from 44KPa to 70KPa. It was found that shear strength of bentonite is increased,when it is treated with soft drinks bottling plant waste and chemical plant waste. However, shear strength of bentonite is decreased when it is treated with paper mill waste. The angle of internal friction of bentonite decreases marginally when treated with paper mill waste and increases marginally when treated with soft drinks bottling plant waste and chemical plant waste.

From table 5 it is evident that there is a decrease in cohesion from 36KPa to 28KPa when sulphate concentration is increased from 0 to 2000ppm (Fluid $F_1$ to $F_2$). But the angle of internal friction is increased from $5^0$ to $12^0$. The shear strength increases from 120KPa to 180KPa. Cohesion is decreased from 34KPa to 30kpa and angle of internal friction is increased from $9^0$ to $12^0$ when ammonical nitrogen concentration is decreased from 1000ppm to 500ppm (Fluid $F_3$ to $F_4$). Shear strength is slightly increased from 150KPa to 160Kpa.

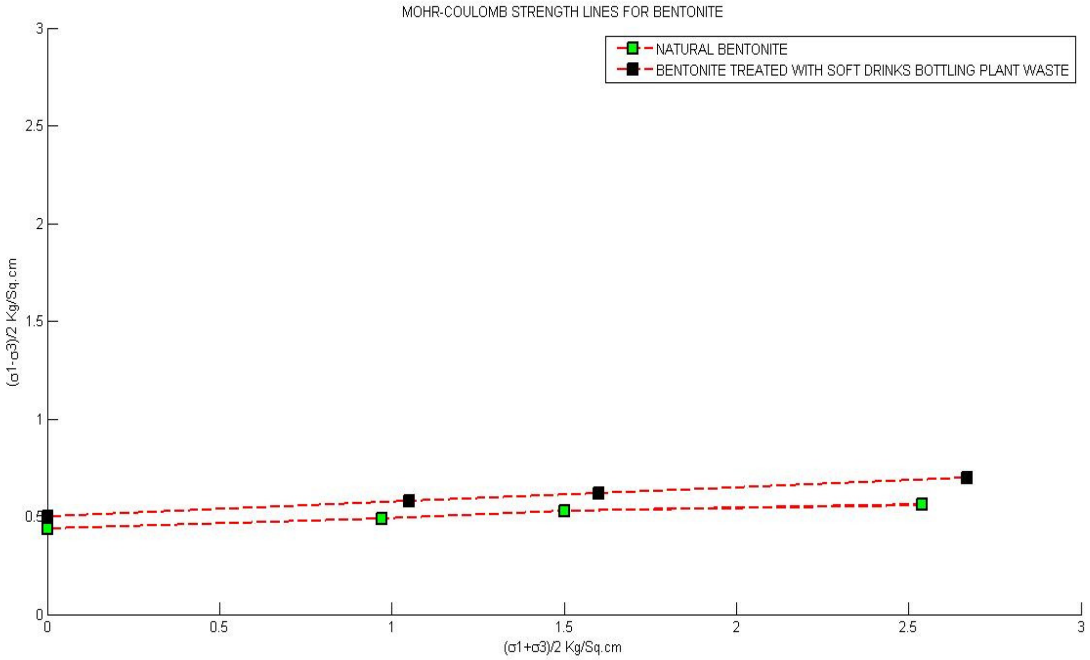
Cohesion is increased from 28KPa to 34KPa and angle of internal friction is decreased from $12^0$ to $9^0$when phosphate concentration is decreased from 1000ppm to 500ppm (Fluid $F_2$ to $F_3$). Shear strength is decreased from 180KPa to 150KPa.

Cohesion is increased from 30KPa to 56KPa and angle of internal friction is decreased from $12^0$ to $7^0$ when fluoride concentration is decreased from 50ppm to 10ppm (Fluid $F_4$ to $F_5$). Shear strength is increased from 160KPa to 180KPa.From the results it can be seen that there is increase in shear strength of Bentonite with increased concentrations of phosphates and sulphates. It is also observed that the shear strength of non-swelling soils is reduced on treatment with paper mill waste, Dairy waste and Pharmaceutical waste.

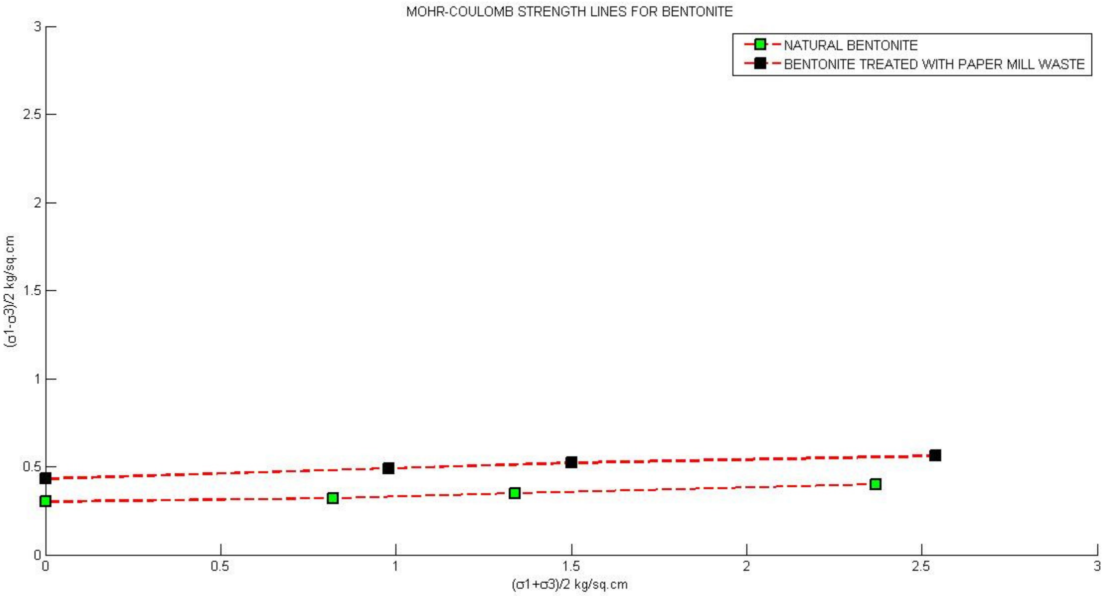
BENTONITE TREATED WITH CHEMICAL PLANT
WASTE



BENTONITE TREATED WITH BOTTLE WASTE



## BENTONITE TREATED WITH PAPER MILL WASTE



## VI. CONCLUSIONS

The following conclusions can be drawn from the results and discussions.

1. The effect of paper mill waste is to considerably reduce the liquid limit of bentonite. Soft drinks bottling plant waste and chemical plant waste increase the liquid limit or bentonite.

2. Increase of phosphates and ammonical nitrogen concentration in the pore fluid increases the liquid limit of bentonite. However interaction with sulphates and fluorides reduces the liquid limit of Bentonite.

3. Interaction with the three effluents, causes a marginal increase in the plastic limit of Bentonite.

4. Phosphate, ammonical nitrogen and sulphates show negligible effect on the plastic limit of bentonite.

5. Treatment with paper mill waste increases the pH of bentonite. However, treatment with soft drinks bottling plant waste and chemical plant waste reduces the pH of bentonite.

6. The undrained shear strength of Bentonite is reduced after treatment with paper mill waste. But soft drink bottling plant waste and chemicals plant waste increases the undrained shear strength of Bentonite.

7. There is increase in the shear strength of Bentonite with increased concentration of sulphates and phosphates. There is a slight increase in the shear strength with decreased concentrations of fluorides and ammonical nitrogen.
8. The undefined mechanism of plastic limit is reflected in this study also.
9. Soil – industrial waste water interaction depends essentially on the soil type, mineralogy and structure and also the chemical composition of waste water and its meaningful modeling requires a great deal of further research.
10. Shear strength of kaolinite soil treated with paper mill waste, Dairy waste and Pharmaceutical waste is reduced when compared to that of natural Kaolinite.

## VII. REFERENCES

[1] Hasan A. Al-Sanad et al (1994) – “Effect of oil contamination on shear strength of sands”- ASCE.
[2] Chandrasekharan.S (1992) – “Effect of polluted water on the Physico-chemical properties of clayey soils” – Summer school on ground contamination from waste disposal activities and their solutions, REC, Calicut, 1992, pp 38-40.
[3] I.S: 2720 (part V) – 1965 – “Determination of liquid and plastic limits”.
[4] I.S: 2720 (part XXVI) – 1973 – “Determination of pH value”.
[5] Krishna Swamy .N.R. et al (1995) – “Effect of chrome tanning effluent on cohesive soils”, IGC-95.
[6] Kumapley N.K (1985) – “the effect of chemical contamination on soil strength”- proc.XI ICSMFE, pp. 1199-1201.
[7] Lambe . T.W (1958) – “The structure of compacted clay” ASCE 84 : SM 2 : 1654.
[8] Lambe. T.W (1953) – “The structure of inorganic clays” ACSE 316.
[9] Murthy .V.N.S – “Soil mechanics and Foundation Engineering”.
[10] Srivastava .R.K, Singh .M &Tiwari .R.P (1994) – “Laboratory study of soil interaction behaviour” Industrial waste water – XIII ICSMFE, 1994, New Delhi.