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Study on the salinity and pH and its effect on geotechnical properties of soil in south-west region of Bangladesh

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Abstract: The soil in the south-west region of Bangladesh has much salinity and pH. The high salinity and pH may lead the changing of geotechnical properties of soils. The study zone is the south-west region of Bangladesh. Samples have been collected from 22 different locations of 8 districts (Khulna, Jhalkathi, Satkhira, Bagerhat, Borguna, Vola, Pirojpur and Potuakhali). The properties of soil obtained from all laboratory tests are specific gravity, plastic limit, liquid limit, shrinkage limit, particle size distribution (percentage of sand, silt and clay), moisture content, unit weight, shear strength, compression index, recompression index, initial void ratio, and preconsolidation stress. The soil used in this investigation is "Inorganic silts of medium compressibility and organic silts" as per Casagrande Plasticity Chart. The variation of different properties of soil with salinity and pH has been evaluated in graphical representation. A specific trend in varitation is obtained. The specific gravity of soil is almost same and the there is no variation with salinity and pH. Moisture content decreases with salinity but increase upto peak and then starts to decrease with pH. Shrinkage limit and plastic limit decrease with salinity and pH. Liquid limit and unit weight increase with salinity but decrease with pH. Undrained shear strength, recompression index increase with salinity and pH. Compression index increases with salinity but do not vary with pH. Initial void ratio increases upto peak then decreases with salinity but do not vary with pH. Preconsolidation stress increases upto peak then decreases with salinity but increases with pH.

Keywords: *Salinity, pH, Engineering properties, Physical properties, Soil salinity test*

1. Introduction:

Salinity and pH are common parameters used to characterize pore fluids of all geo-materials. Salinity is the amount of dissolved salt in pore fluid. Saline soil is a non-alkali soil containing soluble salts, mostly sodium chloride (NaCl). Other salts such as magnesium chloride ($MgCl_2$), potassium chloride (KCl), gypsum ($CaSO_4.2H_2O$), sodium sulphate ($NaSO_4.2H_2O$) and magnesium sulphate ($MgSO_4$) may also be present. (Salman *et al.* 2011). After cyclonic storm AILA ripped the south-west part of Bangladesh one year ago, thousands of acres of land are turning into a vast wasteland due to increasing salinity in these areas. Saline soils may have some unfavorable properties such as high compressibility, low bearing capacity and swelling capability. (Chittaranjan *et al.* 2011). Addition of salt solution sharply increases the undrained shear resistance of soil (Naeini *et al.* 2011).The soil pH is a measure of the acidity or basicity in soils. PH leads to changes in anion and cation exchange capacity of soil to a small extent (T.S. Umesha et al. 2012). pH of soil can also be defined by acid rain and growing industrialization in this region. Acid rain results in changes in physico-chemical characteristics of soil due to cation exchange (P. Sharma et al. 2011). The high salinity in the soils of this region may have been consequently changing geotehcnical properties of soils from the past.The soil salinity and pH in the south west region of Bangladesh are growing day by day.

Figure-1: *Salt affected land in South-west region of Bangladesh*

Objectives:

The objectives of this study are as follows:

i. To study the salinity and pH in soil in south west region of Bangladesh
ii. To determine the geotechnical properties of the soil
iii. To evaluate the variation and relationship of different properties of soil with salinity and pH.

2. Methodology:
2.1 Flow Chart

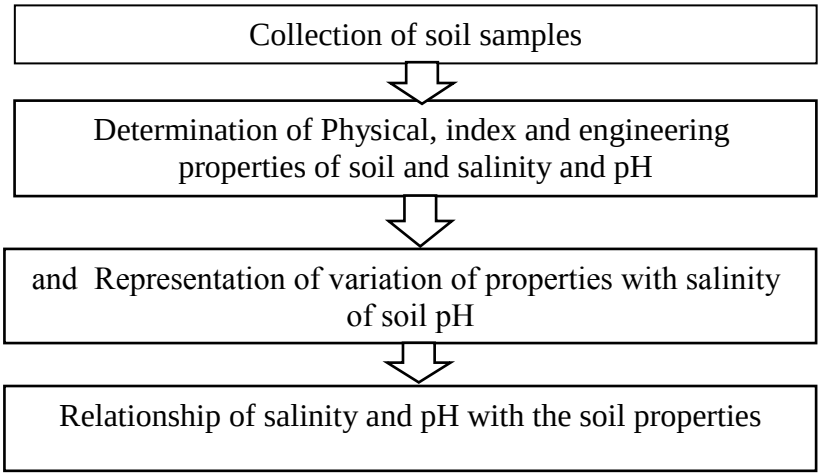

Figure 2: Flow Diagram of Methodology

2.2 Collection of Soil Samples:
Soil samples were collected from 22 different locations of south-west region. The locations are:

Khulna-
- Koyra
- Khalishpur
- Nurnagar
- Jaynagar
- Mailmari
- Dakop
- Botiaghata
- Shipyard
- Sonadanga
- Paikgachha

Satkhira-
- Shyamnagar
- Debhata
- Assasuni

Potuakhali-
- Baufol
- Dasmina

Bagerhat-
- Bagerhat Sadar
- Chitolmari

Jhalkathi-
- Hetalbunia

Pirojpur-
- Hajigonj

Vola-
- Vola Sadar
- Charpation

Borguna-
- Amtoli

The areas are roughly marked by red indications in the map below.

Figure 3: Locations of soil sample collection indicated in Bangladesh map

2.3 Determination of Engineering and Physical Properties of Soil:

The following tests were done to determine the physical and engineering properties, salinity and pH of soil samples collected.

- Specific Gravity (ASTM D854)
- Atterberg Limit (ASTM D 4318)
- Grain Size Analysis (ASTM D 422)
- Moisture Content (ASTM D 2216-90)
- Unit Weight (ASTM D 1556-00)
- Shear Strength (ASTM D 2166)
- Consolidation (ASTM D 4186)
- Salinity (Titration – BS 1993)
- pH (ASTM D 4972-01)

2.3.1 Salinity Test of Soil

Preparation of test specimen

i. The soil sample was dried in an oven at 105 +/- 5^{o} C.
ii. 100 mL distilled water was added with 100g powder of soil sample.
iii. It was stirred to make suspension and allowed to keep 24 hours to settle.
iv. 25 m L of clear suspension was obtained by filtering.

Test procedure

i. 20 m L filtered extract was taken.
ii. 3 drops of potassium chromate was added as indicator.
iii. The sample was titrated with $Ag(NO)_3$ solution. The volume of $Ag(NO)_3$ solution was recorded when the solution became reddish color.

Calculation

Chloride ion content

$= [(X – 2)*50] / S$ mg/L

Where, x= Volume of Ag $(NO)_3$

S=Filtered sample taken (20 mL)

2.3.2 pH Test of Soil

This test method covers the measurement of the pH of soils .This measurement determines the degree of acidity or alkalinity in soil materials suspended in water. The procedures are

i. It was began with an air dried soil that had been sieved through a No. 10 sieve to remove the coarser soil fraction. Air drying the soil is necessary to accomplish sieving and to control the amount of water present at the time of measurement.
ii. Approximately10 g of air dried soil was weighed out. The soil was placed into a glass container and approximately 10 mL of water was added. It was mixed thoroughly and was let stand for 1 h.
iii. The mixture was filtered through filter paper for 24 hours.
iv. The fresh water remaining was collected in a beaker.
v. The remaining water pH was read on pH meter.

3. Illustrations:

Table 1 : The results of the tests done on 22 soil samples are shown in the tables below:

	Test	Specific gravity	Liquid limit (%)	Plastic limit (%)	Shrinkage limit (%)	Unit weight (g/cc)	Untrained shear strength (kPa)	Initial void ratio	Compression index	Recompression index	Preconsolidation stress (kPa)	Salinity (gm/L)	pH
Shyamnagar	2.72	49	29	14.2	30.51	2.03	22.4	2.78	0.83	0.11	220	8.25	7.70
Debhata	2.55	47	34	21	80.77	1.79	5.05	5.19	1.90	0.33	430	3.23	7.79
Koyra	2.69	43	32	14.9	52	1.51	15.5	1.73	0.65	0.10	176.6	1.4	8.13
Hetalbunia	2.70	43	30	18.82	37.62	1.97	53.5	3.3	0.81	0.09	110	2.1	8.37
Dakop	2.69	41	33.6	27.93	27.93	0.95	12.17	5.92	1.20	0.19	100	3.05	8.07
Mailmari	2.70	40	28.3	29.41	29.41	1.95	5.7	1.19	0.44	0.08	186.2	2.55	7.86
Assasuni	2.73	37	27	15.6	41.08	1.89	20.5	1.03	0.44	0.04	294	1.25	9.34
Botiaghata	2.70	36	26	9.9	29	1.38	9.3	0.95	0.31	0.09	294.3	0.45	9.73
Nurnagar	2.54	39	28	10	82	1.24	30.3	0.3	0.23	0.02	215.6	0.2	9.49
Dakop	2.71	44	32	11.7	61	1.31	5.1	1.67	0.40	0.09	196.2	2.55	8.72
Shipyard	2.71	42	30	15	52.29	1.97	17.75	1.80	0.51	0.06	215.6	1.4	8.03
Shonadanga	2.71	54	32	21.9	52	1.44	12.43	1.87	0.57	0.15	245	0.31	8.01
Bagerhat	2.69	31	29	37.55	33	2.07	19.71	1.03	0.19	0.04	110	0.72	7.99
Khalishpur	2.72	35	29	16.2	42	1.77	20.24	1.19	0.49	0.09	196.2	0.85	9.41
Hajigonj	2.73	45	33	22.92	41.64	1.88	26	0.96	0.42	0.06	94	0.48	7.67
Boufol	2.70	43	32	39.13	33.1	2.07	62.5	1.08	0.33	0.05	103	0.9	7.62
Vola	2.72	39	31	34.62	37.99	1.90	18.75	0.97	0.18	0.03	235.2	0.35	8.35
Charpation	2.70	30	22	38.46	31	1.76	49.74	1.01	0.20	0.01	421.4	0.45	8.33
Dasmina	2.71	42	33	22.4	59.18	2.0	18.75	1.63	0.70	0.14	232	0.15	9.86
Chitolmari	2.72	129	58	26.59	43	2.04	39.79	1.26	0.56	0.08	440	4.4	7.49
Amtoli	2.72	41	33	30.43	41	2.0	12.9	0.92	0.28	0.06	245	0.4	7.53
Paikgachha	2.71	34	28	14.1	47.5	1.82	44.4	1.20	0.47	0.1	148.1	0.5	8.80

Location	**Field classification**	**Grain size distribution**		
		Sand %	**Clay %**	**Silt %**
Shyamnagar	Clay gray	23	69	12
Debhata	Silt with organic dark gray	49	10	41
Koyra	Clayey silt gray	5	83	12
Hetalbunia	Silty clay	3.5	30	66.5
Dakop	Silty clay gray	1.2	78.8	20
Mailmari	Clayey silt gray	1.2	45.8	23
Assasuni	Clayey silt gray	7	81	12
Botiaghata	Clayey silt gray	4	83	13
Nurnagar	Black	4.5	69.5	26
Dakop	Clayey silt gray	3.5	71.5	25
Shipyard	Silty clay gray	11	89	0
Shonadanga	Clayey silt gray	5	81.5	13.5
Bagerhat	Clayey silt gray	7	88	5
Khalishpur	Clayey silt gray	6	80	14
Hajigonj	Clay gray	3	82	15
Boufol	Silty clay brown	4	83.5	12.5
Vola	Clayey silt gray	4	83.2	12.8
Charpation	silt gray Clayey	4	83	13
Dasmina	Clayey silt gray	5	83	12
Chitolmari	Clay gray	4	82.5	13.5
Amtoli	Silty clay gray	5.5	81.5	13
Paikgachha	Clayey silt gray	6	82	12

3.1 Plasticity Chart:

From the Casagrande Plasticity Chart, 21 soil samples are in same category. They are in MI or OI group (Inorganic silts of medium compressibility and organic silts). And 1 sample is in the MH or OH group (Inorganic silts of high compressibility and organic clays).

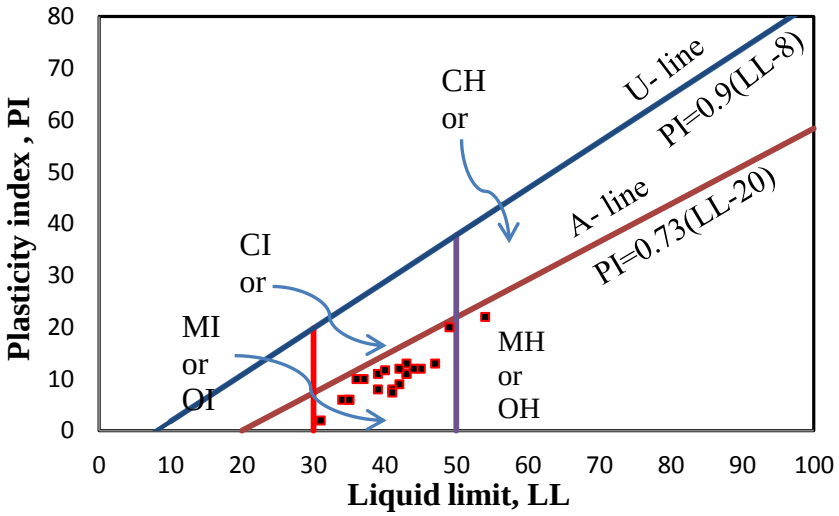

Figure 4: Casagrande Plasticity Chart

Table 2: Soil Classification according to Casagrande Plasticity Chart

Major divisions	Group symbols	Typical name
Silts & clays (liquid limit less than 50)	MI	Inorganic silts of medium compressibility
	CI	Inorganic clays of medium plasticity
	OI	Organic silts , organic silty clays (low plasticity)
Silts & clays (liquid limit greater than 50)	MH	Inorganic silts of high plasticity
	CH	Inorganic clays of high plasticity
	OH	Organic clays (medium to high plasticity),organic silts

3.2 Variation of Soil Properties with Salinity

3.2.1 ***Variation of Specific gravity with Salinity and pH***

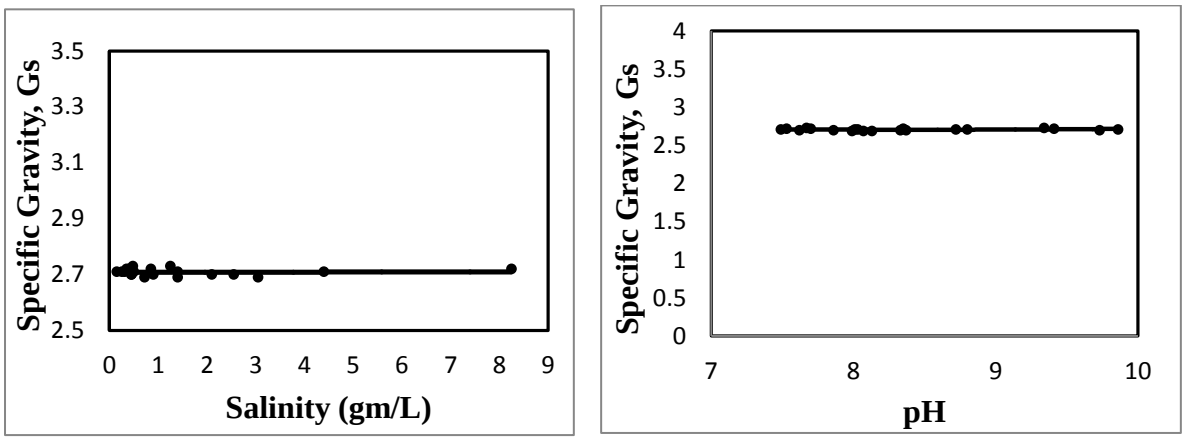

Figure 5: Effect of Specific gravity on Salinity and pH

Specific gravity of all soil samples is almost same. From the graph a parallel horizontal line is obtained and it is seen that there is no / small variation of Specific gravity with salinity and pH.

3.2.2 Variation of Moisture Content with Salinity and pH

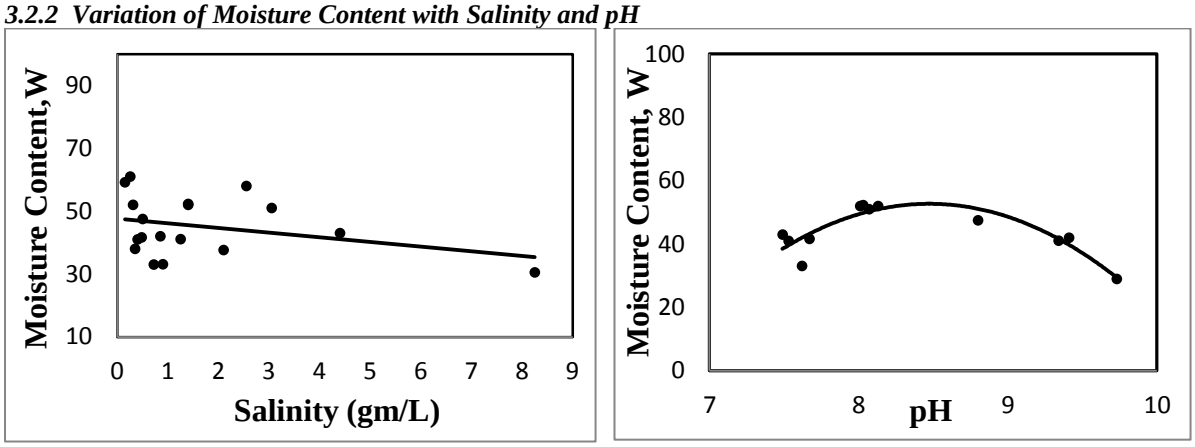

Figure 6: Effect of Moisture Content on Salinity and pH

These graphs show a decreasing line and it can be said that the moisture content decreases with the increasing of salinity and the variation line of moisture content with pH is a convex shaped line. The line increases with a peak and after the peak it decreases.

3.2.3 Variation of Atterberg limits with Salinity and pH

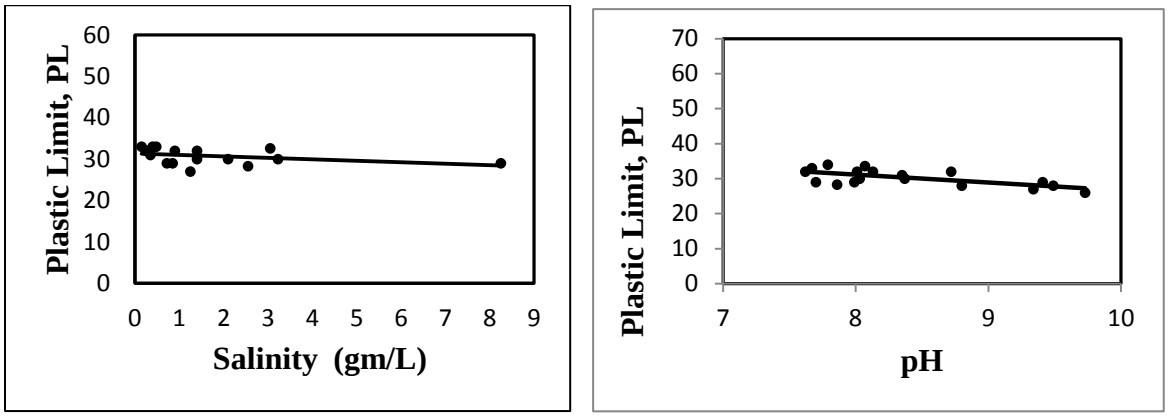

Figure 7: Effect of Plastic Limit on Salinity and pH

This graph shows a slightly decreasing line and it can be said that there is small decreasing trend of plastic limit with salinity. The variation of plastic limit with pH is shows that pH decreases gradually with the increasing pH.

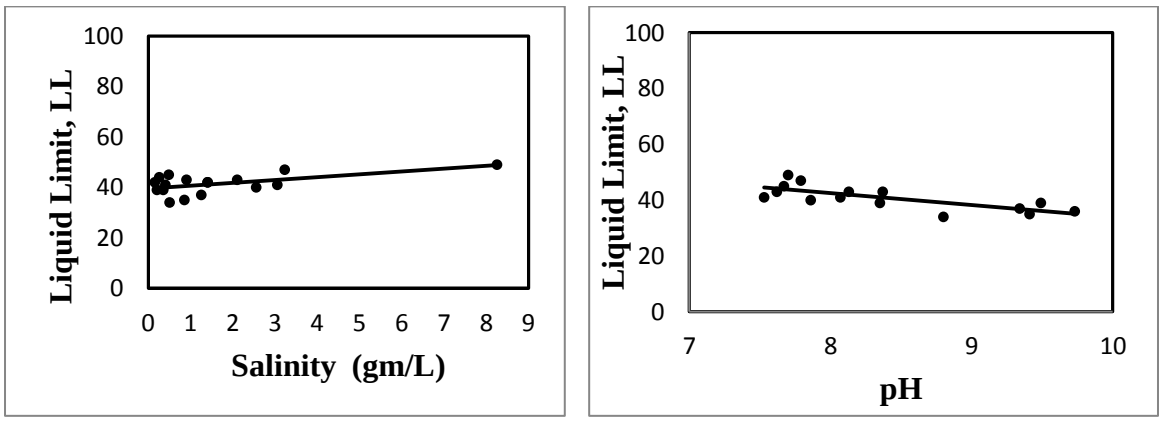

Figure 8: Effect of Liquid Limit on Salinity and pH

From graphical representation it can be seen that the liquid limit increases with the increasing value of salinity and the behavior of liquid limit with pH is decreasing with increasing pH.

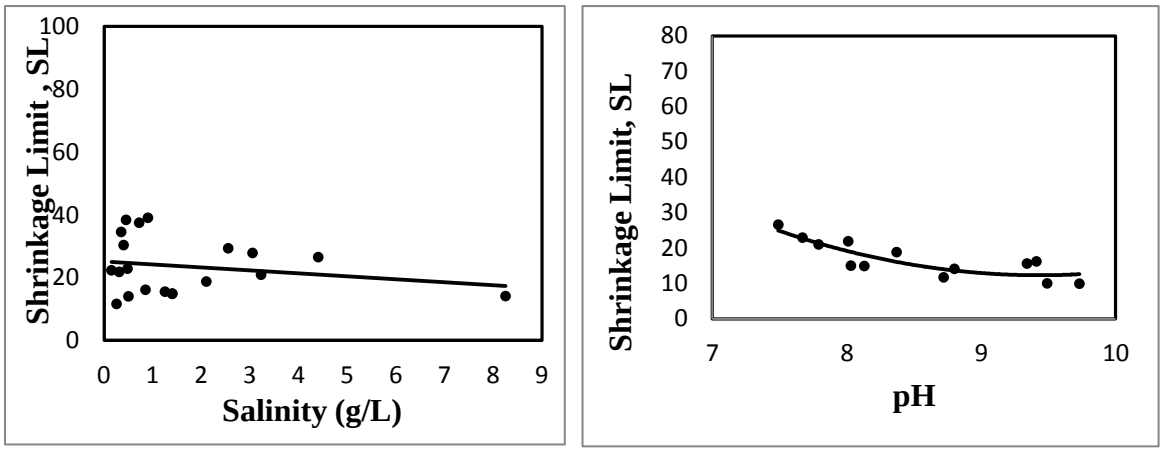

Figure 9: Effect of Shrinkage Limit on Salinity and pH

A decreasing line is obtained from graph. So it is found that the shrinkage limit decreases with salinity. The behavior of shrinkage limit with change in pH is a decreasing concave line. So it can be illustrated that shrinkage limit decreases with increase in pH.

3.2.4 Variation of Unit weight with Salinity and pH

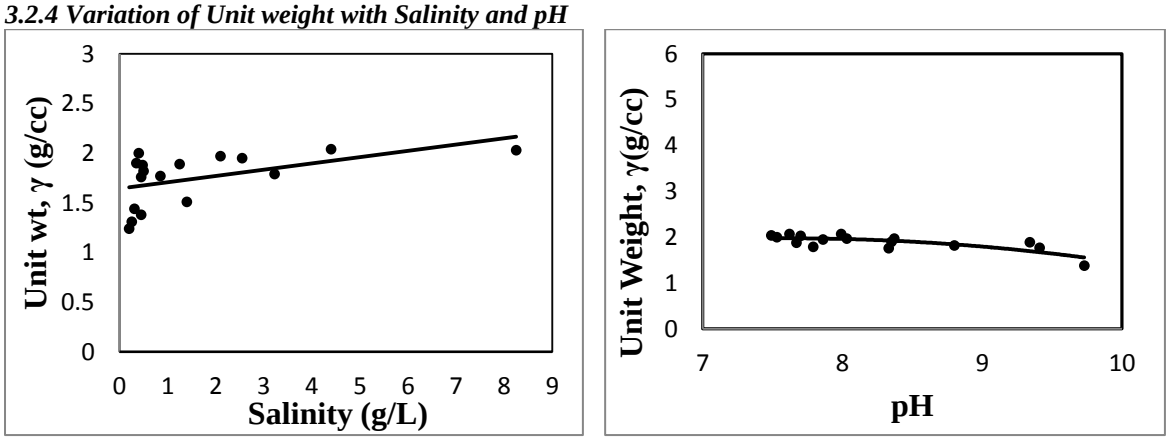

Figure 10: Effect of Unit weight on Salinity and pH

Above Figure illustrates that the unit weight increases with salinity and gradually decreases with pH.

3.2.5 Variation of shear strength with Salinity and pH

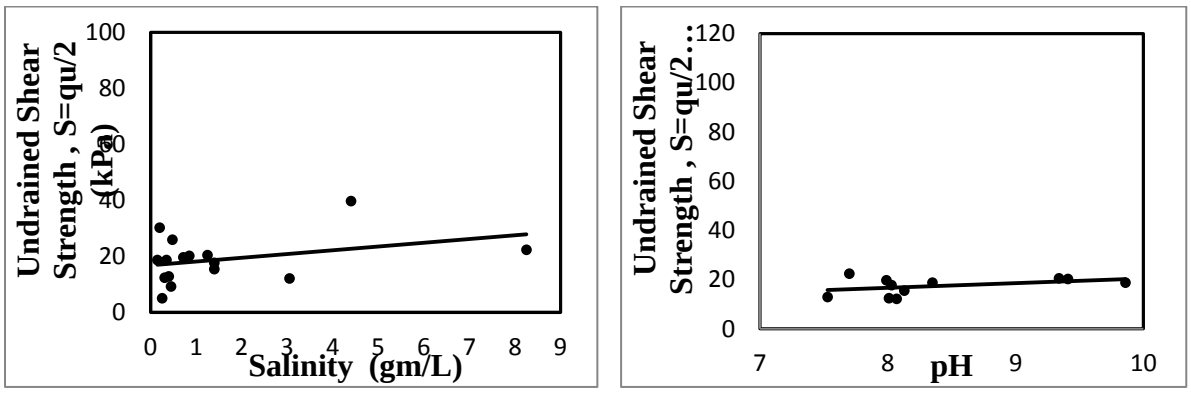

Figure 11: Effect of Shear strength on salinity and pH

This graphs show the increasing line with salinity and pH.So it can be said that the undrained shear strength increases with the increasing value of salinity and pH.

3.2.6 Variation of Initial Void Ratio with Salinity and pH

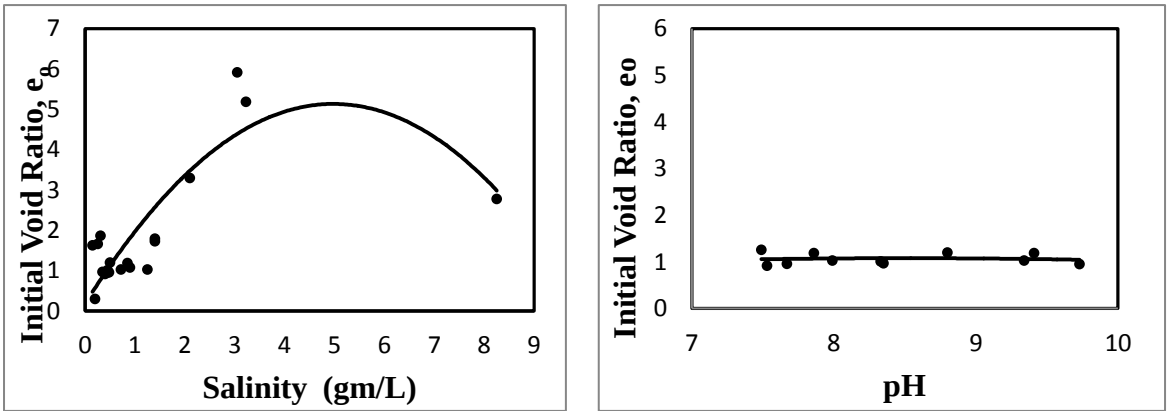

Figure 12: Effect of Initial Void Ratio on Salinity and pH

A convex curve has been found and a peak point of maximum value can be obtained. So it can be said that the value of Initial void ratio increases with salinity upto the peak point and then it starts to decrease. Another figure illustrates the variation of initial void ratio with increase in pH in south-west region of Bangladesh. The variation is an almost horizontal line. So the initial void ratio does not vary much with pH.

3.2.7 Variation of Compression Index with Salinity and pH

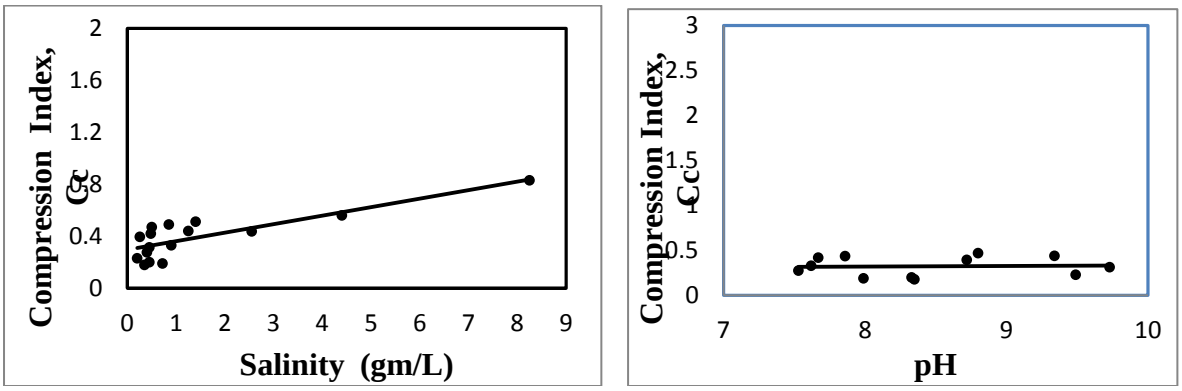

Figure 13: Effect of Compression Index on Salinity and pH

An increasing trend line has been found from graph. So it can be said that the value of compression index increases with salinity and change in behavior of compression index with pH is almost linear as illustrated by the figure above. The behavior shows a less / no variation of compression index with pH.

3.2.8 Variation of Recompression Index with salinity and pH

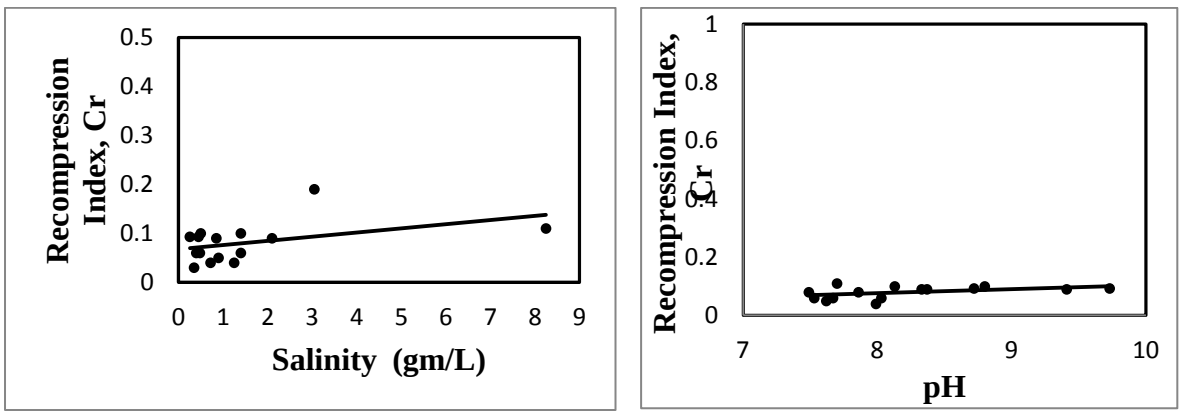

Figure 14: Effect of Recompression Index on Salinity and pH

An increasing line has been found. So it can be said that the value of recompression index increases with salinity and as illustrated by another figure it can be said that recompression index varies almost linearly with increase in pH. There is a less increasing variation in the behavior of recompression index with pH.

3.2.9 Variation of Preconsolidation stress with Salinity and pH

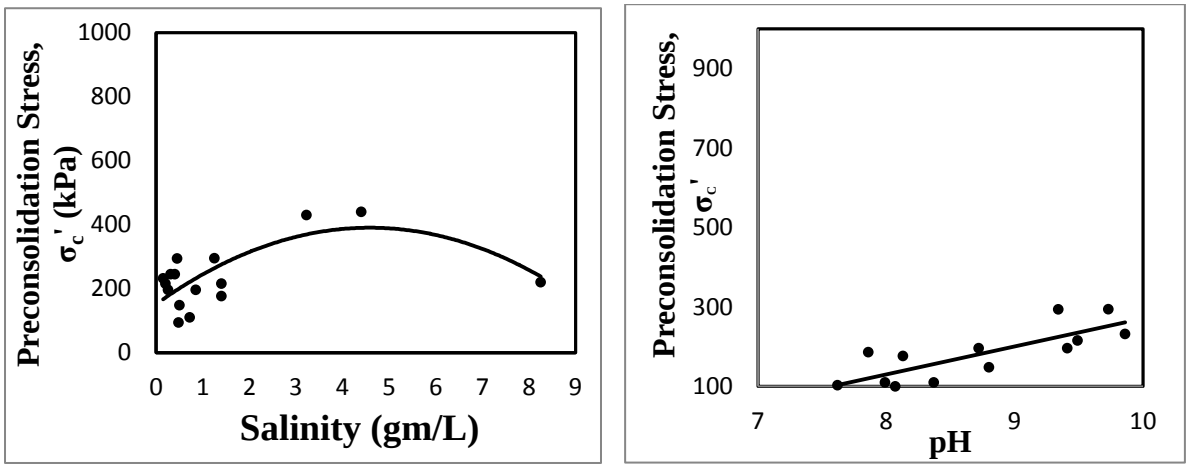

Figure 15: Effect of Preconsolidation stress on Salinity and pH

First graph shows a convex curve having a peak point of maximum value. So it can be said that the value of preconsolidation stress increases with salinity upto the peak point and then it starts to decrease. Preconsolidation stress varies considerabely with pH. The variation line is an increasing line. So it can be said that the preconsolidation stress increases with pH.

4. Conclusions:

The soil in the south-west region of bangladesh has much salinity and pH which resulted in the consequently changing geotehcnical properties of soils from the past. The salinity directly affects the consistency as well as strength properties of the soil. From the previous study it has been found that the physical and engineering property of soil changes based on the type of salt present. The variation is different for the different type of salt as well as the soil type. In the soil the salinity is mostly sodium chloride (about 85 percent), with lesser amounts of sulfate, magnesium, calcium and potassium in decreasing concentrations. So only chloride ion has been tested in this result and from the study theoretical relationship of geotechnical properties with salinity and pH has been obtained.

Table 3: The variation of soil property with Salinity and pH

Soil Property	Increase / Decrease with Salinity	Increase / Decrease with pH
Specific gravity	Small variation (negligible)	Small / No variation
Moisture content	Decrease	Increase upto peak then decrease
Plastic limit	Decrease	Decrease
Shrinkage limit	Decrease	Decrease
Liquid limit	Increase	Decrease
Unit weight	Increase	Decrease
Undrained Shear strength	Increase	Increase
Initial void ratio	Increase upto peak then decrease	Small / No variation
Compression index, Cc	Increase	Small / No variation
Recompression index, Cr	Increase	Slightly increasing
Preconsolidation Stress , σc'	Increase upto peak then decrease	Increase

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