Chemical Characterization of Acidic Soils for Geotechnical Applications.

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Abstract. The chemical analysis of soils are need to be conducted for assessing its suitability as a foundation and as a fill material in the earthen dam and water retaining structures. The pH of soil water extract is an important parameter to define acidic and alkaline nature of soils. The acidic soil solutions (with pH value below 6.0) are aggressive in nature for reinforced concrete structures buried in ground due to its corrosive nature. This paper presents the results of chemical analysis of soil samples received from different river valley projects having acidic characters. The pH values of the soil samples were observed to be in the range of 5.10-6.72 indicated acidic composition of soil strata. The results of calcium carbonate, organic matter, total soluble salts, chloride and sulphate are presented in the paper. Dispersive characteristics of soil samples were determined using chemical method. The interpretation of results are presented and discussed.
Keywords: Acidic soil, Chemical properties, Geotechnical behaviour, Dispersive characteristics.

1 Introduction

The use of soils as foundation and fill materials are depends upon their physico-chemical properties. The chemical compositions of soils are the determining factors behind geotechnical behavior of soils under different climatic conditions. The construction of dam embankments, earthen hydraulic structures, canals, mass concrete structures buried in ground therefore need proper investigation of chemical properties of soils for long term sustainability and stability of structures. The chemical analysis of soils for core parameters such as pH, Total soluble salts, Calcium carbonate content, Organic Matter, Soluble Sulphate and Soluble Chlorides are need to be conducted for its suitability as a foundation materials. Besides these core parameters the chemical analysis of soils pore water also need to be analyze for the estimation of Sodium, Potassium, Calcium and Magnesium to established the dispersive characteristics of soils for its application as a fill material in the earthen dam and water retaining structures. Determination of pH of soil water extract is an important parameter to define acidic and alkaline nature of soils. The soil water extract with pH value below 6.0 is the indication of acidic characteristics of soil strata.

1.1 Soil acidity

Soil acidity is common in all regions where precipitation is high enough to leach appreciable quantities of exchangeable base forming cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) from the surface layers of soil. When certain minerals present in soil are disturbed or exposed to atmosphere due to excavation they can get oxidized to form acids. Highly weathered soils are acidic in nature because when such soils are in contact with water, the adsorbed cations leaches in to the soil solution and because of these exchange reactions the soil solutions are acidic in nature. Various categories of soil pH may be arbitrarily described as follows: strongly acid (pH < 5.0), moderately to slightly acid (5.0 - 6.5), neutral (6.5 - 7.5), moderately alkaline (7.5 - 8.5), and strongly alkaline (> 8.5). Acid soils are rare in semi-arid dryland areas of the world; they tend to occur in temperate and tropical areas where rainfall is substantial; conversely, soils of drier areas are generally alkaline. In India, acid soils constitute nearly one-third of the area. Acid soils are widely distributed in the Himalayan regions, Eastern, North-Eastern and in Southern states under varying climatic conditions.

1.2 Effect of Acidic Soil

The hydrogen-ion concentration of soil water solution is of interest in problems involving grouting in weak rocks, soil stabilization processes using lime and resinuous materials, corrosion of metals in contact with soils and reclamation of marine soils[1]. The pH value also helps in interpreting some of the soil chemical tests. The acidic soil solutions are aggressive in nature for reinforced concrete structures buried in ground due to its corrosive nature [2]. It has been reported that soil is generally considered “mildly corrosive” if the sulfate and chloride in soils are below 200 ppm and 100 ppm, respectively, with pH of 5–9 and the resistivity greater than 5,000 ohm. Cm [3-7], The presence of sulfate more than 200 ppm in soils can pose a major risk for the buried-structural materials [8-11[, because it can readily be converted to highly corrosive sulfides by anaerobic sulfate-reducing bacteria. Maslehuddin et al. studied the effect of chloride concentration in soil on the corrosion behavior of reinforcing steels.[12]. The mechanical behavior of soils predominantly depends on mineralogical composition, physicochemical interaction between particles, inter particle forces, pore fluid chemistry and soil structures. Ramesh et al [13] have reported the effect of sulphuric acid on the compaction and strength properties of black cotton soil. Grzegorz Jozefaciuk and Grzegorz Bowanko.[14] reported the effect of acid attack on the crystal structures of aluminosilicate minerals. The pH plays a very important role in the behaviour of clay suspensions. A low pH promotes a positive edge to negative surface interaction, often leading to flocculation from suspension. Stable suspensions or dispersions of clay particles often require high pH condition [15]. The stability of clay particles is affected by low pH because acid attacks clay particles at edges and releases Al ions [16]. There will be marked changes due to acid attack in the crystal structures of aluminosilicate minerals because of dissolution of structural ions and/or rearrangement of the structure [17]. Acidification changes the physical properties of soils, including the shear strength and Atterberg limits [18,19]. These changes in soil physical properties resulting from acidic condition can trigger the erosion. It was reported that the proportion of soil particles with sizes less than 0.01 mm decreased as pH decreased from 6.0 to 2.0. On the other hand, the proportion increased with increasing pH from 6.0 to 10.0, suggesting a decrease in soil particle size. Liquid limit (LL) generally tends to decrease with increasing soil particle size. Since the attractive force between soil particles attributed to the surface tension of pore water decreases with increasing particle size, the soil easily transforms into a viscous liquid with low water content. This supports the finding that LL and I_P decreased significantly with increasing particle size as pH decreased from 6.0 to 2.0[20,21] .

Central soil and materials research station, New Delhi receives soil samples from different multipurpose river valley projects for geotechnical investigations. The chemical analysis of soil water extracts were carried out as per BIS Standard procedures (Different parts of IS: 2720 codes) for their suitability as foundation and fill material.

2 Experimental

Soil samples received from different projects from Himanchal Pradesh and Neighboring country like Bhutan were analyzed as per standard procedures mentioned in IS: 2720 codes. Details of sample size, procedure and IS codes are presented in table -1.

Table- 1. Details of Parameters, Sample size and Testing Methods**.**

Sl. No.	**Name of Test**	**Procedure**	**Quantity required for test**	**Sample size**	**Reference IS : 2720**
1.	pH	pH Meter Direct reading Type	30 g of the soil in 75 ml Distil water	Sample passed on 425-micron IS Sieve.	Part 26
2.	Total Soluble Salts, TSS	Portable Conductivity Meter.	1:10 Soil water extract.	Sample pass on 2mm Sieve.	Part -21
3.	Water Soluble Sulphate	Precipitation method	1:10 Soil water extract. .	Sample passed on 425-micron IS Sieve.	Part 27
4.	Water Soluble Chloride	Volumetric Estimation	1:10 Soil water extract.	Sample passed on 425-micron IS Sieve.	Part 21
5.	Calcium Carbonate	Acid- Base Volumetric Titration	5 g	Sample pass on 2mm Sieve.	Part 23
6.	Organic Matter	Volumetric Redox Titration.	100 Gram Air drying.	Sample pass on 2mm Sieve	Part 22
7.	Dispersive Character	Chemical analysis of pore water extract for determination of Na, K , Ca, & Mg .	Flame Photometric Method.	Sample passed on 425-micron IS Sieve.	ASTM Test Methods D4542

Soil water extract and pH Meter are presented in figure 1 & 2

Fig.1 Soil Water Extract **Fig.2** Determination of pH With pH Meter

Chemical analysis of pore water extract was carried out with the help of Flame photometer equipment (Figure-3) and Interpretation of the results were done with the help of standard graph presented in figure-4.

Fig.3 Flame Photometer

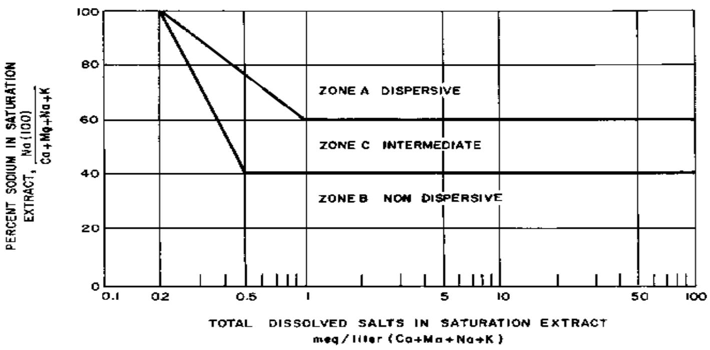

Fig.4. Plot of Total Dissolved Salts (TDS) vs Percent Sodium

3. Observations

Results of chemical analysis of soil samples from three different projects are presented here for reference.

Project 1.(Himanchal Pradesh, India)

Chemical analysis and dispersivity test results of four soil samples from project 1 are presented in table 2 & 3.

Table-2. Results of Chemical Analysis of Soil Samples

Sl.No	Parameters	Sample 1 17/60	Sample 2 17/61	Sample 3 17/62	Sample 4 17/63
1.	pH value as per IS:2720 Pt. 26 1987	5.63	5.69	5.60	5.79
2.	$CaCO_3$ % by wt. as per IS: 2720 Pt. 23. 1976	Nil	Nil	Nil	Nil
3.	Total soluble salts in terms of conductivity millimhos/cm as per IS: 2720 Pt. 21. 1977	0.011	0.015	0.034	0.062
4.	Water soluble sulphate % by wt. as per IS:2720 Pt. 27. 1977	0.025	0.038	0.055	0.117
5.	Water soluble chloride % by wt. as per standard text book.	0.01	0.01	0.03	0.04
6.	Organic matter (%) by wt.	0.40	0.35	0.48	0.20

Table-3. Results of Chemical Analysis of Pore Water Extract

Sample No.	Millequivalent./Lit				Total Cations	Sodium %	Remarks Grade
	Na	K	Ca	Mg			
1	2.19	0.47	0.8	0.4	3.86	56.73	**C**
2	3.20	0.69	0.6	0.2	4.69	68.23	**A**
3	4.12	1.01	1.0	0.6	6.73	61.21	**A**
4	3.44	0.80	0.6	0.2	5.04	68.25	**A**

Project-2 (Himanchal Pradesh, India)

Chemical analysis and dispersivity test results of three soil samples from project 2 from Himanchal Pradesh are presented in table 4 & 5.

Table-4 Results of Chemical Analysis of Soil Samples

Sl. No.	Parameters	Sample 1 18/215	Sample 2 18/216	Sample 3 18/217
1.	**pH** value as per IS:2720 Pt. 26 1987	6.72	6.63	5.49
2.	**$CaCO_3$ %** by wt. as per IS: 2720 Pt. 23. 1976	Nil	Nil	Nil
3.	**Total soluble salts** in terms of conductivity millimhos/cm as per IS: 2720 Pt. 21. 1977	0.0044	0.0043	0.0041
4.	Water soluble **sulphate** % by wt. as per IS:2720 Pt. 27. 1977	0.010	0.009	0.008
5.	Water soluble **chloride** % by wt. as per standard text book.	0.02	0.01	0.01
6.	**Organic matter** (%) by wt.	0.19	0.22	0.31

Table-5. Results of Chemical Analysis of Pore Water Extract

Sample No.	Mili equivalent./l				Total Cations	Sodium %	Remarks Grade
	Na	K	Ca	Mg			
1	0.51	0.27	0.8	0.2	1.78	28.65	**B**
2	0.50	0.32	0.6	0.4	1.82	27.47	**B**
3	0.48	0.26	0.8	0.2	1.74	27.58	**B**

Project-3 (Bhutan)

The results of chemical analysis and dispersivity test of 8 soil samples received from, project 3, Bhutan, are presented in table 6 & 7

Table-6. Results of Chemical Analysis of Soil Samples

Sl. No.	Parameters	Sample 1 20/138	Sample 2 20/139	Sample 3 20/140	Sample 4 20/141	Sample 5 20/142	Sample 6 20/143	Sample 7 20/144	Sample 8 20/145
1.	pH value as per IS:2720 Pt. 26 1987	5.73	5.68	5.71	5.60	5.78	5.10	5.21	6.11
2.	$CaCO_3$ % by wt. as per IS: 2720 Pt. 23. 1976	Nil	Nil	Nil	Nil	Nil	Nil	Nil	1.0
3.	Total soluble salts in terms of conductivity millimhos/cm as per IS: 2720 Pt. 21. 1977	0.029	0.030	0.011	0.033	0.022	0.007	0.004	0.012
4.	Water soluble sulphate % by wt. as per IS:2720 Pt. 27. 1977	0.035	0.038	0.015	0.041	0.020	0.008	0.004	0.010
5.	Water soluble chloride % by wt. as per standard text book.	0.0016	0.0018	0.0010	0.0020	0.0014	0.0010	0.0006	0.0010
6.	Organic matter (%) by wt.	0.31`	0.34	0.29	0.26	0.22	0.39	0.35	0.30

Table-7. Test Results of Pore Water Analysis of Soil Samples

Sample No.	Mili equivalent./l				Total Cations	Sodium %	Remarks Grade
	Na	K	Ca	Mg			
1	0.12	0.009	0.2	0.2	0.53	22.64	**B**
2	0.30	0.03	0.2	0.4	0.93	32.25	**B**
3	0.35	0.02	0.4	0.2	0.97	36.08	**B**
4	0.34	0.03	0.4	0.2	0.97	35.05	**B**
5	0.38	0.03	0.2	0.4	1.01	37.62	**B**
6	0.28	0.02	0.4	0.2	0.90	31.11	**B**
7	0.39	0.03	0.4	0.2	1.02	38.23	**B**
8	0.44	0.02	0.6	0.2	1.26	34.92	**B**

4. Results and Discussion

Project -1.

All the four soil samples were acidic in nature. The pH values varies between 5.60-5.79. (Figure.5) The calcium carbonate contents were found to be nil in all samples. The soluble salts were in the normal acceptable range. The other parameters were also present within permissible limits.

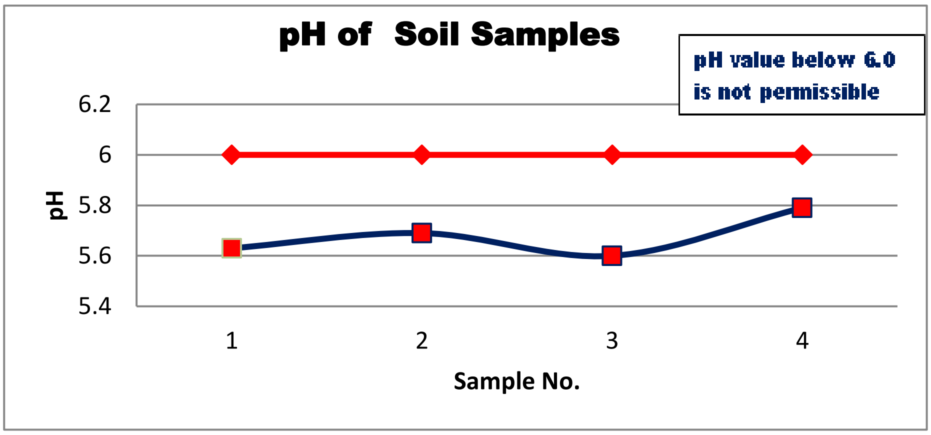

Fig.5 pH of Soil Samples

The results of chemical analysis of pore water extract (Table-3) shows that except sample no.1 which falls in an intermediate range, the remaining three soil samples are of dispersive nature. The zonal categorization of soil samples with soluble sodium percentages of the pore water extract are presented in figure 6.

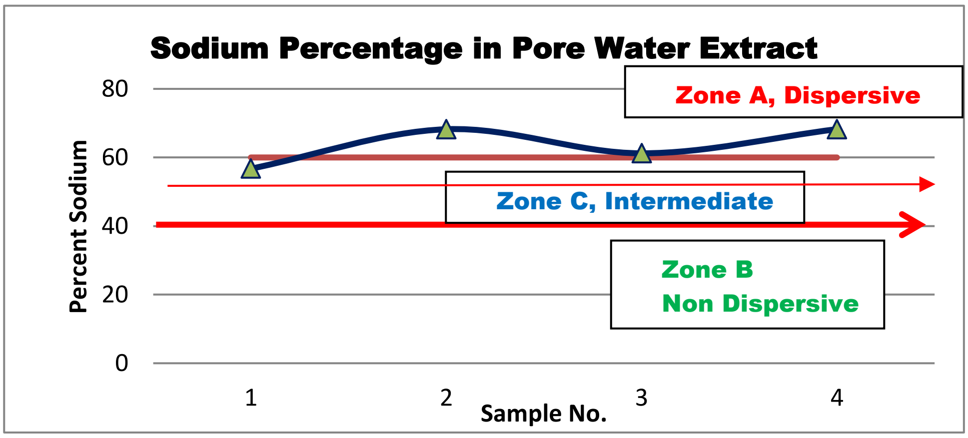

Fig.6 Sodium Percentage in Pore Water Extract of Soil Samples

Project -2.

All the four soil samples were slightly acidic in nature. The pH values varies between 5.49-6.72 (Figure.7) The calcium carbonate contents were found to be nil in all the samples. The other parameters were also present in low concentration. All the four soil samples are non-dispersive in nature and categorized in Zone B as presented in figure 8.

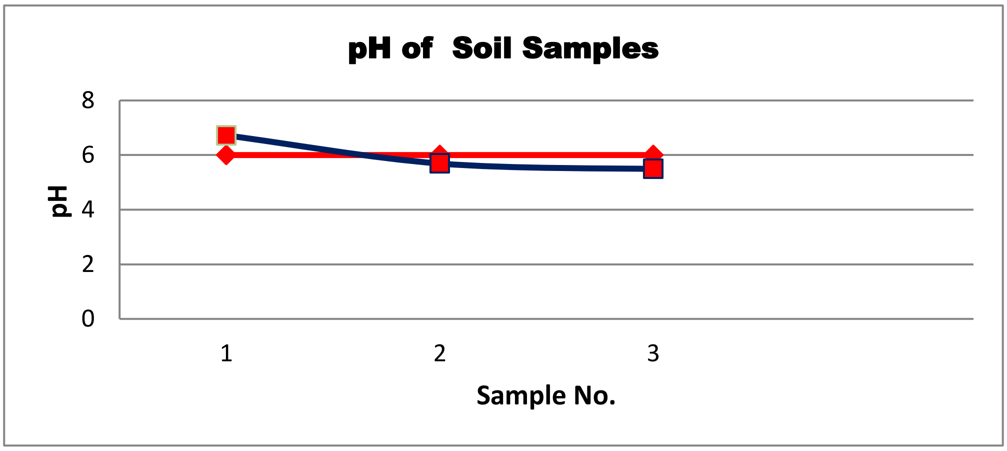

Fig.7. pH of Soil Samples

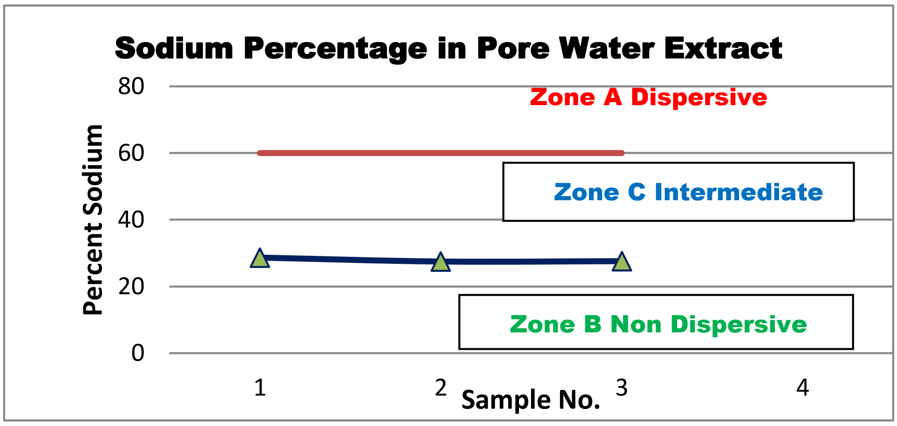

Fig.8 Sodium Percentage in Pore Water Extract of Soil Samples

Project-3

All the eight soil samples were acidic in nature. The pH values varies between 5.10-6.11. (Figure.9) The calcium carbonate contents were found nil in all the samples. The other parameters were also present in normal acceptable range. All the eight soil samples are non-dispersive in nature and categorized in Zone B as presented in figure10.

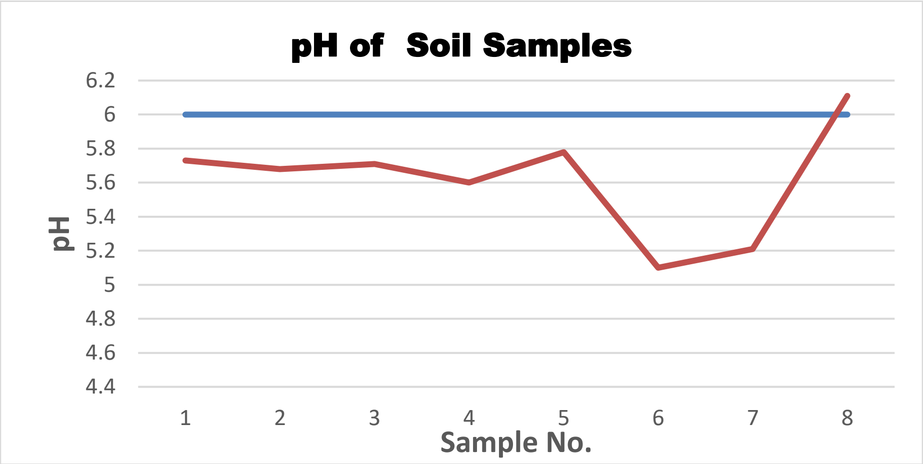

Fig.9. pH of Soil Samples

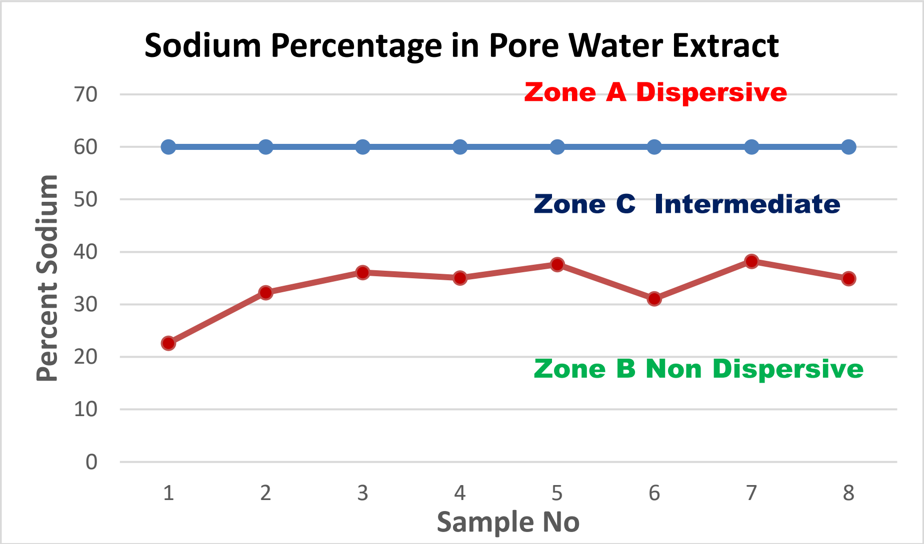

Fig.10. Sodium Percentage in Pore Water Extract of Soil Samples

5. Conclusion

The pH values of most of the soil samples from all the three projects were found to be below 6.0 showing acidic nature. The calcium carbonate contents were almost nil in all these soil samples. The presence of soluble salts contents were also found below 1 mmhos/cm in all these soil samples, showing moderate presence within acceptable range. The presence of soluble sulphate was also observed in some acidic soil samples which may be due to sediments or organic substrates (e.g., peat) that are formed under waterlogged conditions. The organic matter also contributes towards acidity with the presence of humic acid in such peaty soils. The results of chemical analysis of pore water extract shows that some soil samples from Himanchal Pradesh project exhibit dispersive nature along with acidic characters however soils from projects of Bhutan shows non dispersive nature. The interpretation of dispersive behavior of acidic soils thus required more research inputs to understand its diverse behavior. The detailed minerology and correlation with engineering properties should also need to be investigated for further characterization of acidic soils.

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