International Journal of Research in Chemistry and Environment
Vol. 1 Issue 1 July 2011(119-123)
ISSN 2248-9649

Research Paper

Change in Geotechnical Properties of High Plastic Soils on Exposure to Acid Rains of Varying Strength

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Available online at: www.ijrce.org

(Received 13th May 2011, Accepted 26th May 2011)

Abstract - *Acidification of rain caused by air pollutants like sulfur dioxide and oxides of nitrogen etc. reduces the pH as low as 3 to 4. The low H^+ concentration of acid rain falling for a short duration may not affect soil properties instantaneously due to adequate cation exchange capacity of soil. But ever growing industrialization/pollution is increasing its frequency, persistence and the intensity. The frequent, persistent and growing intensity of acid rain will certainly exceed buffering capacity of soil. This will enhance the rate of leaching of cations from the soil to a great extent. Absorption of H^+, SO_4^{2-}, NO_3^- and CO_3^{2-} by the soil particles will alter physical, chemical and engineering properties of soil which cannot be ignored. Therefore it is imperative to examine the properties of soils eroded due to acid rain in order to augment understanding of its influence on geotechnical engineering. The objective of present study is to find out the degree of variation in the texture, physico-chemical and the engineering properties of soil of high plasticity on exposure to acid rains of varying strength. The soil fraction passing 4.75 mm sieve was shaken for eight hours with varying probable simulated strength of acid rain equivalent to normality 0.005N, 0.01N, 0.02N and 0.04N of H_2SO_4 or HNO_3 to study short term influence of acid rain on soil properties. The acidification causes deflocculation of soil particles which directly affects the consistency as well as strength properties of the soil. The paper presents the observed degree of variation in these properties under varying strengths of acid rain.*

Key words: Acid rain, pH, Index Properties, Consolidated undrained etc.

Introduction

Environmental Geo-technology is emerging as an interdisciplinary science, aiming at forecasting, analyzing and solving the geotechnical problems involving the influence of environmental factors [7]. Absorption of gaseous pollutants released during volcanic eruptions and industrial exhausts reduces the pH [6]. Although the H^+ content of acid rain falling for a short duration is very low yet its influence on the physical, chemical and engineering properties of soil will be alarming in near future as ever growing industrialization/pollution will keep on substantially decreasing its pH. The enhanced rate of leaching of cations and absorption of H^+, SO_4^{2-}, NO_3^- and CO_3^{2-} alter its physical, chemical and engineering properties[5] . It is thus one of the most influential environmental factors which directly affect the properties of soil [4]. The present study is carried out on soil of high plasticity collected from Indore to find degree of variation in its texture, physico-chemical and the engineering properties on exposure to acid rains of various simulated strengths.

Material and Methods

The soil sample used in this study was obtained from Indore, Madhya Pradesh, India. The sample was oven dried & sieved using 4.75 mm IS sieve. The down size material was used for further experimental work. The consistency, strength and chemical characteristics of the samples were determined for the soil fraction passing 425 μm sieve.
The results are summarized in Table 1.

1 kg of soil sample was separately shaken for 8 hours with 1 liter of H_2SO_4 and HNO_3 of 0.005N, 0.01N, 0.02N and 0.04N strengths as detailed in table 2. These samples were then kept undisturbed over night. The treated samples were then filtered and air dried. These samples were then used to find their consistency, strength and chemical properties as per Bureau of Indian Standards (IS 2720, BIS 1987 & 1988).

Results

Soil Texture

The soil samples were analyzed before and after acid treatment using scanning electro microscope (SEM) for finding the texture of the soil crystals. The results of SEM analysis for the soil samples before and after acid treatment are presented in figure 1, 2 and 3. It is observed that angularity of the particles is increased which can be attributed to leaching of the cations and subsequent deflocculation.

Mechanical Analysis

The results of mechanical analysis of the soil samples before and after acid treatment are presented in Table 3. The results clearly show that the deflocculation of soil particles predominantly adds to increase in percentage of silt size particles as intensity of acidification increases.

Physico-Chemical Properties

On treating the soil samples with different concentrations of H_2SO_4 or HNO_3 the physico-chemical properties of the soil samples got changed. The pH of the samples correspondingly reduced as the concentration of the acid increased. On acid treatment, the organic matter got digested and thereby its percentage reduced. The observed values are presented in Table 4.

Consistency Characteristics

The values of Liquid limit (W_L), Plastic limit (W_P), Plastic Index (I_p), Shrinkage limit and Free Swell Index for the soil samples before and after acid treatment are presented in Table 5. The degree of variation in the consistency characteristics of the soil depends on factors like type of soil, electrical charge of exchangeable cations absorbed by soil particles and concentration of cations in soil water [5].

Due to the leaching of cations and deflocculation the consistency characteristics of the soil reduced except shrinkage limit. The increase in values of shrinkage limit is attributed to increase in inter particulate distances due to reduction in the forces between soil particles.

Strength Characteristics

The strength characteristics of soil are affected extensively by soil's internal structure and interaction between soil particles. The strength of soil originates mainly from the soil skeleton and electric attractive force between the electric charges absorbed by the soil particles.

The results of the effective cohesion (c'), kg/cm^2 and effective angle of internal resistance (Ø'), degree for untreated and acid treated soil samples is presented in Table 6. The values of effective cohesion (c') and Effective angle of internal resistance (Ø') are observed to be lesser for acid treated soil samples. This is mainly due to reduction in the electric forces as concentration of exchangeable cations reduced on acid treatment.

Further Research

In the present study, an approach to find out the effect of acid rain on high plastic soil from Indore has been established. The study on high plastic soils from other locations viz. Nagpur is in progress. However, the scope of the study is being contemplated to various types of the soils to be collected from different parts of India to establish probable impact of acid rain on geophysical properties. This will help in better understanding of the situations during planning and construction of mega civil engineering structures.

Conclusion

Acid rain results in changes in physico-chemical characteristics of soil due to cations exchange. pH of the soil decreases while the concentration of absorbed H^+ and SO_4^{2-} increases. Grain size distribution of the soil will shift towards finer fractions when subjected to acid rain. The angularity of individual particles will also increase. Acid rain affects the consistency properties of different soils. Leaching of cations will reduce the attractive forces between the soil particles which will lower the overall strength of the soil. The data obtained during the experiments is useful in gauging the damages to the soil that could occur due to the acid rain in future. However the magnitude of the deterioration will depend on persistence and strength of acid rain.

Acknowledgement

The authors extend their sincere thanks to Dr. R.K. Parashar, Associate Prof. NCERT, Sh. N. Sivakumar, Scientist E, CSMRS and Mrs. Abha Sharma for valuable suggestions extended by them. Timely help extended by Sh. Devender Singh and Sh. Anil Vashisht and Sh. Anil Rustagi of CSMRS are gratefully acknowledged. We also extend our sincere gratitude to all the authors whose publications provided us directional information from time to time.

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Table 1 Characteristics of original samples

Characteristic	Result
Liquid limit (W_L) %	67.30
Plastic limit (W_P) %	26.39
Plastic Index (I_p) %	40.91
Shrinkage limit %	6.18
Free Swell Index %	66.67
Particles finer than 0.002mm %	22.90
Particle 0.002mm-0.075mm %	47.70
Particle 0.075mm-0.425mm %	26.10
Particle 0.425 mm-2.00 mm %	2.20
Particle 2.00 mm - 4.75 mm %	1.10
pH	7.11
Organic Matter %	0.70
Effective Cohesion c (kg./cm^2)	0.45
Effective Ø (degree)	16.36

Table 2. Details of sample designation

S. No.	Description	Strength of acid	Designation
1	Original Soil Sample	DW	A
2	1 kg Soil + 50 ml 0.1 N H_2SO_4 + 950 ml Distilled Water	0.005 N	A_S - 1
3	1 kg Soil + 100 ml 0.1 N H_2SO_4 + 900 ml Distilled Water	0.01 N	A_S - 2
4	1 kg Soil + 200 ml 0.1 N H_2SO_4 + 800 ml Distilled Water	0.02 N	A_S - 3
5	1 kg Soil + 400 ml 0.1 N H_2SO_4 + 600 ml Distilled Water	0.04 N	A_S - 4
6	1 kg Soil + 50 ml 0.1 N HNO_3 + 950 ml Distilled Water	0.005 N	A_N - 1
7	1 kg Soil + 100 ml 0.1 N HNO_3 + 900 ml Distilled Water	0.01 N	A_N - 2
8	1 kg Soil + 200 ml 0.1 N HNO3 + 800 ml Distilled Water	0.02 N	A_N - 3
9	1 kg Soil + 400 ml 0.1 N HNO3 + 600 ml Distilled Water	0.04 N	A_N - 4

Table 3 Results of Grain size Analysis of soil before and after acid treatment

Soil Sample	Particle Size (mm)				
	Below 0.002 (%)	0.002 to 0.075 (%)	0.075 to 0.425 (%)	0.425 to 2.0 (%)	2.0 to 4.75 (%)
A	22.90	47.70	26.10	2.20	1.10
A_S - 1	21.00	56.60	20.80	1.10	0.50
A_S - 2	12.30	70.40	14.60	1.80	0.90
A_S - 3	10.40	73.80	13.70	1.30	0.80
A_S - 4	8.70	75.10	14.30	1.10	0.80
A_N - 1	17.80	59.40	20.90	0.90	1.00
A_N - 2	15.60	68.40	13.30	1.80	0.90
A_N - 3	12.40	71.50	12.30	2.90	0.90
A_N - 4	9.60	76.90	10.90	1.80	0.80

Table 4 Physico-Chemical Properties of soil samples before and after acid treatment

Sample	pH	Organic Matter %
A	7.11	0.70
A_S - 1	5.98	0.63
A_S - 2	4.89	0.00
A_S - 3	4.15	0.00
A_S - 4	3.60	0.00
A_N - 1	6.15	0.37
A_N - 2	5.38	0.00
A_N - 3	4.60	0.00
A_N - 4	3.17	0.00

Table 5 Results of Consistency Characteristics of soil samples before and after acid treatment

Sample	W_L, %	W_P %	I_p %	Shrinkage limit, %	Free Swell Index, %
A	67.30	26.39	40.91	6.18	66.67
A_S - 1	61.00	24.70	36.30	8.11	53.00
A_S - 2	59.20	23.40	35.80	8.30	52.00
A_S - 3	56.20	23.20	32.98	9.20	51.00
A_S - 4	55.40	22.27	31.30	9.58	49.00
A_N - 1	65.80	25.80	40.00	6.11	60.00
A_N - 2	62.80	24.60	38.20	7.30	58.00
A_N - 3	56.80	23.30	33.50	8.40	54.00
A_N - 4	54.20	22.00	32.20	10.20	52.00

Table 6 Strength Characteristics of soil samples before and after acid treatment

Sample	Effective cohesion (c'), kg./cm^2	Effective angle of internal resistance (Ø'), degree
A	0.45	16.36
A_S - 1	0.40	15.69
A_S - 2	0.31	15.01
A_S - 3	0.25	14.36
A_S - 4	0.22	13.58
A_N - 1	0.41	15.38
A_N - 2	0.32	14.35
A_N - 3	0.24	13.72
A_N - 4	0.22	13.08

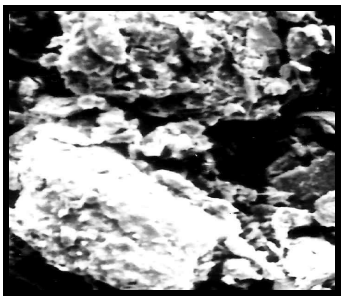
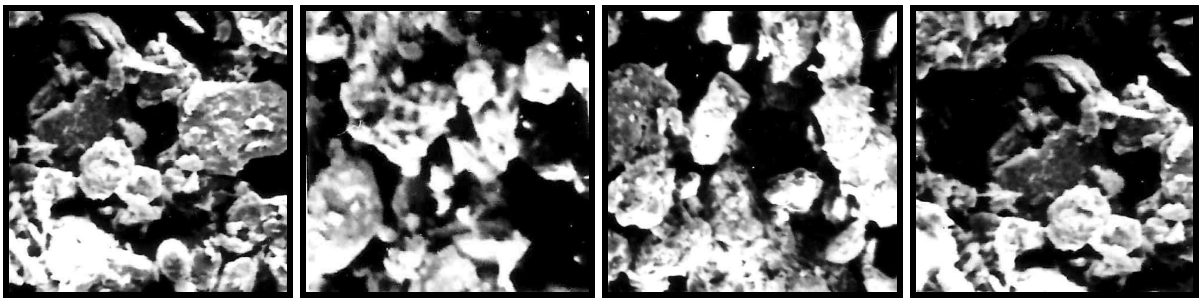
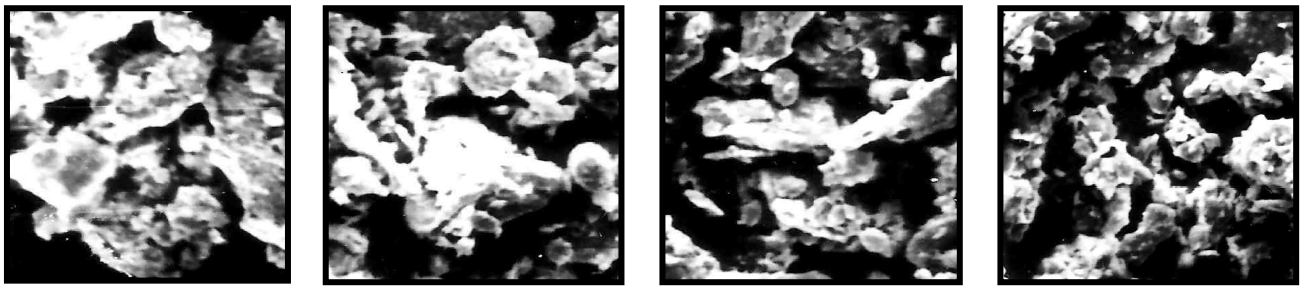


Figure 1: SEM analysis for original sample A



Sample A_S-1 Sample A_S-2 Sample A_S-3 Sample A_S-4

Figure 2: SEM analysis for H_2SO_4 treated samples



Sample A_N-1 Sample A_N-2 Sample A_N-3 Sample A_N-4

Figure 3: SEM analysis for HNO_3 treated samples