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# Acidic Precipitation: An Emerging Cause of Variation in the Engineering Properties of Soils

Pankaj Sharma, Sameer Vyas, N.V.Mahure, R.P.Pathak and Devender Singh

Central Soil and Materials Research Station, Olof Palme, New Delhi, India

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Abstract: Acidification of rain is caused by air pollutants like sulfur dioxide and oxides of nitrogen etc. which reduces its pH as low as 4. Although the H<sup>+</sup> concentration of acid rain falling for a short duration is very low in comparison to cation exchange capacity of soil yet its effect on the physical, chemical and engineering properties of soil needs to be studied. Ever growing industrialization/pollution will increase frequency, persistence and intensity of acid rain. This will certainly enhance the rate of leaching of cations from the soil to a great extent. Absorption of H<sup>+</sup>,  $SO_4^{2-}$ ,  $NO_3^{-}$  and  $CO_3^{2-}$  by the soil particles is likely to alter its engineering properties. 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 particularly when used in fields, embankment or in earth fill dams. Objective of this study is to find degree of variation in the engineering properties of soil of different plasticity when exposed to acid rains having different pH. Soil samples were collected and acidified with varying probable simulated strength of acid rain equivalent to normality 0.005N, 0.01N, 0.02N and 0.04N of H<sub>2</sub>SO<sub>4</sub> / HNO<sub>3</sub>. The consistency and strength characteristics of the samples are determined for the soil fraction passing 425 µm sieves. The paper presents the observed degree of variation in these properties under varying strengths of acid rain.

**Keywords**: Environment, consistency, Physico-Chemical, angle of shearing resistance, cation exchange capacity.

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## 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 <sup>[1]</sup>. Absorption of gaseous pollutants released during volcanic eruptions and industrial exhausts reduces the pH <sup>[2]</sup>. Although the H<sup>+</sup> content of acid rain falling for a short duration is very low yet its influence on the engineering properties of soil may become 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<sup>+</sup>, SO<sub>4</sub><sup>2-</sup>, NO<sub>3</sub><sup>-</sup> and CO<sub>3</sub><sup>2-</sup> alter these properties <sup>[3]</sup>. It is thus one of the most influential environmental factors which directly affect the properties of soil <sup>[4]</sup>. The present study aims at finding the degree of variation in the engineering properties of the soils of different plasticity when exposed to acid rain of varying concentration.

### EXPERIMENTAL

**Materials:** Two soil samples Sample A of medium plasticity and Sample B of high plasticity were used in this study. These samples were oven dried & sieved using 4.75 mm IS sieve. The down size material was used for further experimental work. The consistency and strength characteristics of the samples were determined. The results are summarized in **Table-1**.

| Characteristic                              | Sample |       |
|---|--------|-------|
|   | А      | В     |
| Liquid limit (W <sub>L</sub> ) %            | 37.50  | 67.30 |
| Plastic limit (W <sub>P</sub> ) %           | 20.30  | 26.39 |
| Plastic Index (I <sub>p</sub> ) %           | 17.20  | 40.91 |
| Shrinkage limit %                           | 15.29  | 6.18  |
| Free Swell Index %                          | 48.62  | 66.57 |
| Particles finer than 0.002mm %              | 13.20  | 22.90 |
| Particle 0.002mm-0.075mm %                  | 57.50  | 47.70 |
| Particle 0.075mm-0.425mm %                  | 23.80  | 26.10 |
| Particle 0.425 mm-2.00 mm %                 | 3.40   | 2.20  |
| Particle 2.00 mm - 4.75 mm %                | 2.10   | 1.10  |
| рН  | 6.80   | 7.11  |
| Organic Matter %                            | 0.54   | 0.70  |
| Effective Cohesion c (kg./cm <sup>2</sup> ) | 0.31   | 0.45  |
| Effective Ø (degree)                        | 24.62  | 16.36 |

Table-1: Characteristics of original samples A and B

## **EXPERIMENTAL METHODS**

1 kg of each soil sample was separately shaken for 8 hours with 1 litter of  $H_2SO_4$  /  $HNO_3$  50:50 solution of 0.005N, 0.01N, 0.02N and 0.04N strengths as detailed in **Table-2**.

| S1. | Description  | Strength | Desig | nation |
|-----|--|----------|-------|--------|
| No. |  | of acid  |       |        |
| 1   | Original Soil Sample + 1 lit Distilled Water (DW)  | DW       | А     | В      |
| 2   | $1 \text{ kg Soil} + 25 \text{ ml } 0.1 \text{N } \text{H}_2\text{SO}_4 + 25 \text{ ml } 0.1 \text{N } \text{HNO}_3 + 950 \text{ ml } \text{DW}$   | 0.005 N  | A1    | B1     |
| 3   | $1 \text{ kg Soil} + 50 \text{ ml } 0.1 \text{N } \text{H}_2\text{SO}_4 + 50 \text{ ml } 0.1 \text{N } \text{HNO}_3 + 900 \text{ ml } \text{DW}$   | 0.01 N   | A2    | B2     |
| 4   | $1 \text{ kg Soil} + 100 \text{ ml } 0.1 \text{N } \text{H}_2 \text{SO}_4 + 100 \text{ml } 0.1 \text{N } \text{HNO}_3 + 800 \text{ml } \text{DW}$  | 0.02 N   | A3    | B3     |
| 5   | $1 \text{ kg Soil} + 200 \text{ ml } 0.1 \text{N } \text{H}_2\text{SO}_4 + 200 \text{ ml } 0.1 \text{N } \text{HNO}_3 + 600 \text{ ml } \text{DW}$ | 0.04 N   | A4    | B4     |

| Table- 2: | Details | of | sample | designation |
|-----------|---------|----|--------|-------------|
|-----------|---------|----|--------|-------------|

These samples were then kept undisturbed over night. The treated samples were then filtered and air dried. The soil extract of each treated sample was prepared and ultimate pH of this sample was determined. The results are presented in **Figure -1**.



### Figure 1: pH of original and treated soil samples

These samples were then used to find their consistency and strength properties as per Bureau of Indian Standards<sup>5-7</sup>.

### **RESULTS AND DISCUSSIONS**

**Mechanical Analysis:** The results of mechanical analysis of the soil samples before and after acid treatment are presented in **Fig.2 and Fig.3**. The results clearly show that as intensity of acidification increases the deflocculating of soil particles which predominantly increase the percentage of silt and clay size particles.

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Figure 2: Grain size analysis of original and treated sample A



Fig. 3: Grain size analysis of original and treated sample B

**Consistency Characteristics:** The values of Liquid limit ( $W_L$ ), Plastic limit ( $W_P$ ) and Plastic Index ( $I_p$ ) for the soil samples before and after acid treatment are presented in **fig. 4**.



**Figure 4:** Atterberg Limits of soil samples A and B before and after acid treatment Results of Shrinkage limit and Free Swell Index presented in **Table 3**.

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| Sample | Shrinkage | Free Swell |
|--------|-----------|------------|
|        | limit, %  | Index, %   |
| А      | 15.29     | 48.67      |
| A1     | 18.60     | 43.20      |
| A2     | 19.10     | 41.90      |
| A3     | 19.80     | 40.10      |
| A4     | 20.30     | 39.40      |
| В      | 6.18      | 66.67      |
| B1     | 8.18      | 56.22      |
| B2     | 8.69      | 54.19      |
| B3     | 9.03      | 51.16      |
| B4     | 9.23      | 48.24      |

# Table- 3: Results of Shrinkage limit and free swell index forthe soil samples before and after acid treatment

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 <sup>[3]</sup>. Due to the leaching of cations and deflocculation the consistency characteristics of the soil reduced except shrinkage limit. 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<sup>2</sup> and Effective angle of internal resistance ( $\emptyset$ '), degree for untreated and acid treated soil samples is presented in **Table- 4**.

| Sample | Effective cohesion (c'), | Effective angle of internal |
|--------|--------------------------|-----------------------------|
|        | kg./cm <sup>2</sup>      | resistance (Ø'), degree     |
| А      | 0.31                     | 24.62                       |
| A1     | 0.19                     | 24.10                       |
| A2     | 0.16                     | 23.40                       |
| A3     | 0.15                     | 21.90                       |
| A4     | 0.13                     | 21.20                       |
| В      | 0.45                     | 16.36                       |
| B1     | 0.37                     | 15.60                       |
| B2     | 0.32                     | 14.80                       |
| B3     | 0.25                     | 13.60                       |
| B4     | 0.23                     | 12.90                       |

The values of effective cohesion (c') and Effective angle of internal resistance ( $\emptyset$ ') 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.

The percent variation in the effective angle of internal resistance ( $\emptyset$ ) is presented in **figure 5**. It is observed that in sample B (high plastic soil) the influence of acid rain is comparatively more than that of sample A (medium plastic soil).



# Fig. 5: Percent variation of effective angle of internal resistance (Ø') for sample A and B on treatment with acid rain of different strength

#### FURTHER RESEARCH

In the present study, an approach to find out the effect of acid rain on soils of medium and high plasticity has been carried out. However, seeing the percent difference in the degree of variation in various parameters on treatment with equivalent intensity of acid rain 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

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. 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 type of soil, persistence and strength of acid rain.

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\*Correspondence Author: Pankaj Sharma; Central Soil and Materials Research Station, Olof Palme Marg, N. Delhi-110016 India.