Iranian Journal of Engineering Geology
Autumn 2018, Vol.11, No.3

Experimental study on the effect of acid and alkaline rains on geotechnical properties of fine-grained soil

Mustafa Momeni[1], Ajalloeian Rassoul[2*], Bayat Meysam[3]

Abstract

In the current study, the effects of acid and alkaline rains on the physical properties of a particular type of clay with low plasticity is evaluated. In order to reproduce the process of interaction between artificial rain and soil, an infiltration setup was fabricated. Solutions of diluted sulfuric acid (H_2SO_4) and dissolved sodium hydroxide (NaOH) were used to create acidic or alkaline rains, respectively. Distilled water was also used as a reference pH value. Subsequently, the reconstituted samples in a mold are infiltrated by acid or alkaline rains in different pH levels and different fluxes of rainfall. Atterberg limits, Coefficient of permeability, California bearing ratio (CBR) test, and unconfined compressive strength (UCS) of the soil samples were evaluated, to investigate the changes of the mechanical properties of the soil after being exposed to acid or alkaline rain. The obtained results indicated that acidic contamination had a strong influence on the strength characteristics of soils, and the mineralogy of the clay fraction as well as the concentration of acid in the pore fluid could significantly influence the stress-strain behavior of studied soil. However, further decrease in pH (pH=3) and increase in rain fluxes (20 years) caused a significant reduction of the strength. Furthermore, the results indicate that the values of the LL, PI and the soil permeability has increased and the unconfined compressive strength and the CBR has decreased as the artificial rain become more acidic or alkaline, and precipitation years increased from one-year to twenty-years.

Keywords: *Acid rain, Geotechnical properties, Clay, CBR test, Unconfined compressive strength*

[1] M.Sc, Department of Civil Eng, Najafabad branch, Islamic Azad University, Najafabad, Iran
[2] Professor, Department of Geology Eng, University of Isfahan, Isfahan, Iran
[3] Assistant Prof, Department of Civil Eng, Najafabad branch, Islamic Azad University, Najafabad, Iran
*** Corresponding Author**

Extended Abstract:

1. Introduction

Previous studies indicate that the changes in physical characteristics of soil due to pH-induced changes can affect the development of the water erosion and geotechnical properties. Soil sensitivity to pH-induced changes will depend on several factors. The more important these are the presence or absence of carbonates in the soil, the total cation exchange capacity (CEC) which is mainly determined by the content of clay and soil organic matter. Kamon et al. (1997) investigated the effects of the pH level of artificial acid rain on the geotechnical and physico-chemical characteristics of soils by two test methods (i.e. the infiltration and the soak methods). The results of the tests indicate that the acidic condition significantly altered the physico-chemical characteristics (such as cation concentration of the outflow and soaked water and exchangeable cation concentration) of the soil as compared to engineering characteristics (such as liquid limit). Bakhshipour et al., (2016) studied the effects of acid rain on the physico-chemical and microstructural properties of residual soils. The results indicate that low pH and high fluxes of acid rain result in a decrease of maximum dry density and soil compressive strength and as well as an increase in the permeability, optimum water content and liquid limit of the soil.

2. Materials and methods

In the current study, artificial penetration of water into the soil specimens with pH values of 3 (i.e. strongly acidic condition) 5.6 (i.e., mildly acidic condition), 7 (i.e. neutral condition) and 7.6 (i.e. alkaline condition) was prepared by adding certain volume of nitric acid (HNO_3) and sulfuric acid (H_2SO_4) or ammonium solution (NH_4^+) to deionized distilled water to make different ranges of acid and alkaline rain. The flux of the water in the penetration system was determined based on the average annual precipitation in Isfahan (i.e. 120 mm/year) as reported by the Isfahan Meteorological Organization. On the top of the specimens, transparent PVC pipes with a height of 100 cm and an inner diameter of 15.1cm was used which permits water to percolate through the soil specimen, and the tank are placed at the bottom of the specimens to collect the outflow water from the soil specimens during the tests process. The flux of the water in the penetration system has been calculated according to the following equation assuming that one-third of the wastewater or precipitation infiltrates into the ground:

$$\textit{The flux of water} = \frac{1}{3}(R_{ave} \times A) \qquad (1)$$

Where, R_{ave} is the average annual precipitation in *mm/year* and A is the cross sectional area of the specimen in cm^2. In the current study, the time intervals of 1, 10 and 20-years of precipitation for various pH values are considered. According to the average water annual precipitation in Isfahan (i.e. 120 mm/year) and cross-sectional area of the specimens (i.e. 181.45 cm^2), the amount of the fluxes of water solution using Eq. (1) for 1, 10 and 20-years were determined to be equal to 720, 7200 and 14400 *ml*, respectively. After that, all the remoulded specimens have been constructed with the diameter of 15.19 cm and the height of 11.6 cm by static compaction with five layers of equal thickness. The under-compaction method as suggested by Ladd (1978) was adopted when compacting the soil to achieve a more uniform specimen. The soil specimens prepared at the corresponding optimum moisture content (16.8%) and maximum dry density (i.e. 17.95 kN/m^3). After preparation the soil specimens in CBR moulds, the soil specimens were placed into the infiltration setup. Then, specimens were exposed to fluxes of water with a desired pH value (3, 5.6, 7 and 7.6) and desired precipitation fluxes equivalent (1, 10 or 20-years). Atterberg limits, Coefficient of permeability, California bearing ratio (CBR) test, and unconfined compressive strength (UCS) of the soil samples were evaluated, to investigate the changes of the mechanical properties of the soil after being exposed to acid or alkaline rain.

3. Tests results

The obtained results indicated that acidic contamination had a strong influence on the strength characteristics of soils, and the mineralogy of the clay fraction as well as the concentration of acid in the pore fluid could significantly influence the stress-strain behavior of studied soil. However, further decrease in pH (pH=3) and increase in rain fluxes (20 years) caused a significant reduction of the strength. Furthermore, the results indicate that the values of the LL, PI and the soil permeability has increased and the unconfined compressive strength and the CBR has decreased as the artificial rain become more acidic or alkaline, and precipitation years increased from one-year to twenty-years.

4. Conclusion

An experimental study was performed on clay specimens to investigate effects of pH-induced changes on the geotechnical properties of the soil using Atterberg limit, permeability, California bearing ratio, and unconfined compressive strength testing. Based on results, the following conclusions could be drawn:

With increasing in the acidity or alkalinity of artificial rain and increasing the rainfall fluxes, the soil properties experience more serious changes, this phenomenon will lead to a decrease in the strength of the soil and increase in LL, PI and the coefficient of permeability.

References:

Beygi A, Ahmadi H, Asor A, 2007, Air Hygiene and Methods for Combating Environmental and Industrial Pollutants, Andisheh Rafi Publications.

Ghiasuddin M, 1979, Air Pollution (Resources, Effects and Control), Tehran University Publications.

Abadi A, 1992, Investigating Air Pollutants in Tehran City, Environmental Health Unit, Ministry of Health and Medical Education

Isfahan Meteorological and Environmental Bureau, 2006-2008, Meteorological stations of Mobarakeh, Lenjan, Shahreza cities.

Bakhshipour Z, Asadi A, B. K. Huat B, Sridharan A, Kawasaki S, 2016, Effect of Acid Rain on Geotechnical Properties of Residual Soils, Soils and Foundations,56(6):1008–1019.

Gratchev I, Towhata I, 2011, Compressibility of Natural Soils Subjected to Long-Term Acidic Contamination, Environ Earth Sci , 64:193–200, DOI 10.1007/s12665-010-0838-2.

Bakhshipour Z, Asadi A, B. K. Huat B, Sridharan A, 2016, Long-Term Intruding Effects of Acid Rain on Engineering Properties of Primary and Secondary Kaolinite Clays, Int. J. of Geosynth. And Ground Eng, 2:21, DOI 10.1007/s40891-016-0059-1.

Du Y, Li Wei M, R. Reddy K, Liu Z, Jin F, 2014, Effect of Acid Rain PH on Leaching Behaviour of Cement Stabilized Lead-Contaminated Soil, Journal of Hazardous Materials, 271, 131–140.

Kamon M,Ying C, KATSUM T, 1997, Effect of Acid Rain on PHysic-Chemical and Engineering Properties of Soils, Soils and Foundations,Vol.37 No.4, 23-32.

Meteorological Organization of Isfahan Province, Investigation of Air Pollution in Isfahan City Using Rainfall Analysis Method, 2014, Database of Meteorological and Environmental Bureau of Isfahan Province, 4-120.

DU Y, Jiang N, Shen S, Jin F, 2012, Experimental Investigation of Influence of Acid Rain on Leaching and Hydraulic Characteristics of Cement-based Solidified/Stabilized Contaminated Clay, Journal of Hazardous Materials, 225– 226.

Sunil B.M, Nayak S, Shrihari .S, 2006, Effect of PH on the geotechnical properties of laterite, Engineering Geology, 85, 197-203.

Ola, S., 1978, Geotechnical properties and behaviour of some stabilized Nigerian lateritic soils. Q. J. Eng. Geol. Hydrogeol. 11 (2), 145–160.

Mitchell K., 1993, Fundamental of Soil Behavior, p. ^pp. 406: John Wiley and Sons.

van Olphen H., 2005, An Introduction to Clay Colloid Chemistry, New York: wiley.

Wang, Y.-H., Siu, W.-K., 2006, Structure characteristics and mechanical properties of kaolinite soils. I. Surface charges and structural characteriza- tions. Can. Geotech. J, 43 (6), 587–600.

Sridharan, A., El-Shafei, A., Miura, N., 2002, Mechanisms controlling the undrained strength behavior of remolded Ariake marine clays. Mar. Georesources Geotechnol. 20 (1), 21–50.

Sridharan, A., Rao, S., Murthy, N., 1988, Liquid limit of kaolinitic soils. Geotechnique 38 (2), 191–198.

Gratchev I, Towhata I, 2015, Compressibility of Soils Containing Kaolinite in Acidic Environments, KSCE Journal of Civil Engineering, DOI: 10.1007/s12205-015-0141-6.

Gratchev, I.B., Sassa, K, 2009, Cyclic behavior of fine-grained soils at different PH values, J. Geotech. Geoenviron. Eng. 135 (2), 271–279.