Study on the effect of pH on the Atterbergs limits of kaolinitic and montmorillonitic clay

Nivedya K, School Of Engineering, CUSAT
nivedyabalakrishnan@gmail.com

Dr. Shobha Cyrus, Professor in Civil Engineering, School Of Engineering, CUSAT
sobharoymthomas@gmail.com

Abstract

In the present scenario due to the urbanisation and industrialisation much of the air, water and land have become polluted. Any kind of pollution has direct or indirect effect on the properties of soil. So in the present study the effect of pH on the properties of two soil were studied. In the present study effect of pH on the Atterberg limits of two soils were investigated using different pore fluids at different pH. Different Pore fluids such as NaCl, KCl, NaOH and KOH at different pH were selected such that pH varying from 6.5 to 13 could be obtained.

From the present study it could be seen that for the same solution with increase in pH the liquid limit was found to increase with decrease in pH both in the case of kaolinite and bentonite. Plastic limit is of lesser importance with regard to pH, both in the case of kaolinite and bentonite. The effect of pH on Shrinkage limit in the case of kaolinite and bentonite showed extremely opposite behavior.

Keywords: pH, kaolinite, montmorillonite, plasticity characteristics, shear strength

Introduction

In recent years, due to population growth, progressive living standard, and industrial progress, much of the air, water and land have become polluted. Open dumps, chemical and industrial wastes as well as many other sources cause these problems. All types of pollution have direct or indirect effects on ground soil properties.

In the past few decades, a great deal of research has been conducted to understand the influence of pore water chemistry on the strength characteristics of fine-grained soils, while little has been done to understand the effects of pH, especially acidic water, despite the fact that acid contamination has become an increasing concern around the world. Acidic contamination of soil can occur through natural processes such as weathering of mudstone or due to anthropogenic activities such as municipal waste storage, accidental spills or acidic rains etc. This problem been recognized recently, and a few studies have been performed to investigate the effects of pH on soil properties. Yet the effect of pH of pore fluids on the strength of soil remains unclear. This study seeks to shed light on this issue by providing laboratory data concerning the variations in atterberg limits of two soils subjected to pore fluids at different pH.

Montmorillonite and kaolinite are two most common clay minerals observed in natural clays. The various studies shows that the behavior of kaolinite and montmorillonite are extremely different when subjected to same environmental conditions. So in this study kaolinite and bentonite has been chosen to investigate the effect of pH on the geotechnical properties.

Materials used

Kaolinite

Commercially available kaolinite is used in this study. This was collected from English IndiaClayLimited,Kochuvely,Trivandrum,
Kerala. The kaolinite which procured for the complete investigation was thoroughly mixed for uniformity and then preserved in double layer of polythene bags.

**Bentonite**

Bentonite and was procured from Associate ChemicalsP(Ltd), Kochi, Kerala. The percentage of water present in bentonite depends upon the climatic conditions, since bentonite belongs to the montmorillonite group, has great affinity for moisture. Hence, the bentonite, which was procured for the complete investigations, was thoroughly mixed for uniformity and then preserved in double layer of polythene bags. These bags were stored in airtight bins.

**Pore Fluids used**

Chlorides are widely distributed in nature usually in the form of sodium, potassium and calcium salts. Pore fluids such as NaCl, KCl, NaOH and KOH were selected since they represent many of the industrial effluents. Different solutions of NaCl, KCl, NaOH and KOH at different normalities were prepared in the laboratory and their pH were measured using pH meter. The concentration of the solutions were finally chosen such that the pH of atleast two solutions were close to each other. Concentration of solutions were fixed such that pH ranging from 6 to 13 were obtained.

**Preparation of samples**

Solutions of NaCl, KCl, NaOH and KOH at different pH were prepared in the laboratory. Kaolinite and bentonite were soaked in chosen solutions for 3 months. The containers were made air tight in order to prevent the evaporation of the solution. Samples were collected from each containers at 15th day, 30th day and 60th day and required tests were conducted

**Effect on liquid limit**

From the results obtained it is observed that for the same solution increase in pH resulted in the decrease of liquid limit. The trend is similar in both acidic range and alkaline range. Also with increase in curing period the liquid limit is found to be decreasing. liquid limit is increasing with decrease in pH. Also with increase in curing period liquid limit decreases. At lower pH flocculation of particles increases, thus liquid limit increases. In the acidic range, a decreasing trend in the values of liquid limit is observed with increase in the hydrated ion radius. In the alkaline range with decrease in hydrated ion radii, liquid limit is found to increase in both lower pH and higher pH. The trend was found to be similar in the case of bentonite also.

In the case of kaolinite besides the edge to face contacts which contributes to increased resistance when pore fluids of lower dielectric constants are used, the presence of natural cementing agents and cementing compounds formed by stabilisation process can influence the liquid limit

![Fig.1.Variation in Liquid Limit with curing period](image-url)
following manner. In the case of bentonite the surface area is much larger and for the same weight of clay the double layer water is large compared to the free water and there is very little edge to face contact in the normal case. Attractive forces are not much significant at larger spacing. Hence it is the variation of the double layer thickness which affects the fluid content at liquid limit. For kaolinite it has lower surface area and because of the positive edged areas a tendency to form edge face contact is more evident, except at highly alkaline pH. The amount of pore fluid at pore space at liquid limit is composed of the double layer fluid and the free fluid. Since the amount of double layer fluid per unit weight of soil is small in kaolinite, most of the fluid is free fluid and the weak edge to face bonds allow the flow of the particles at a lower fluid content.

**Effect on shrinkage limit**
One of the important physical properties of the clay in which engineers are interested is the volume change in water content on climatic changes. Shrinkage limit is an extremely useful parameter in quantitatively identifying the soil fabric. For a curing period of 60 days, at higher pH 53% decrease in shrinkage limit was observed in the case of kaolinite, while 150% increase was observed in the case of bentonite when NaCl is used. Also at lower pH 50% decrease in shrinkage limit is observed for kaolinite while 200% increase was noted for bentonite. When KCl is used at higher pH 56% decrease in shrinkage limit was observed for kaolinite while 112% increase was observed in the case of bentonite. Similarly at lower pH 52% decrease in shrinkage limit was observed for kaolinite while 200% increase was observed for bentonite. In the case of kaolinite inter particle arrangements In the case of montmorillonitic clay particle arrangements are nearly parallel, so there is greater shrinkage with lower shrinkage limit values at higher liquid limit. predominates. The similar behavior was also observed in the case of addition of lime to such soils. The increase in liquid limit with ionic changes is in relation with higher shrinkage limits.

![Fig.2.Variation in Shrinkage Limit with curing period](image)

The shrinkage limit of kaolinite generally follows the mechanism of liquid limit. It is observed that for the same solution with increase in pH, there is decrease in both liquid limit and shrinkage limit in the case of kaolinite.

![Fig.3.Variation in Liquid Limit with Shrinkage Limit](image)

In contrast with increase in pH of the same solution liquid limit decrease while shrinkage limit increases for bentonite. The
Conclusions

The conclusions drawn from the present study can be summarised as follows.

- In the case of kaolinite liquid limit was found to be decreased as pH increased when same pore fluids at used. In kaolinite Vander waals force of attraction between the inter particles plays major role in the variation of liquid limit. Also the amount of double layer fluid per unit weight of soil is small in kaolinite, so most of the fluid is free fluid and the weak edge to face bonds allow the flow of the particles at a lower fluid content. This could be the reason for the decrease in liquid limit.

- For the same solution Liquid limit was found to be decreased as pH increased in the case of bentonite. This could be due to the reason that as the pH increases the thickness of the diffuse double layer decreases and thus reduction in liquid limit occurs.

- The plastic limit is of lesser importance. There is no distinct trend in changes of plastic limit with pH were observed. Change in pH does not cause significant variations in the plastic limit of both kaolinite and bentonite. The plasticity index is thus more directly related to liquid limit than plastic limit.

- In the case of bentonite as the period of curing increased the liquid limit was found to be decreased. With time particle flocculation and adsorption on the diffuse double layer increases, this may cause the reduction in liquid limit with increase in curing period. Variations are more significant in the case of bentonite.

- For the same solution it was found that shrinkage limit decreased as pH increased in the case of kaolinite. In kaolinite shrinkage limit follows the mechanism of liquid limit. Also with increase in curing period, shrinkage limit was found to be decreased.

- On contrary for the same solution shrinkage limit was found to be increased with increase in pH in the case of bentonite. In bentonite shrinkage limit does not follows the mechanism of liquid limit. Also with increase in curing period shrinkage limit was found to be increased for same solution.

Reference

