pH and Electrical Conductivity of Cement-Treated Peat

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Abstract The constructional activities on peat soil are avoided which is due to its poor load-bearing capacity and high compressibility. Therefore, it always requires making the peat conducive in terms of its both strength and compressibility so as to undergo an infrastructural operation over it. However, apart from strength and compressibility criteria, there lie other two parameters (i.e., pH and electric conductivity) which also need to give emphasis while making any constructional activity over it. This paper studies the importance of accounting the pH and electric conductivity (EC) of peat soils as a significant parameter from the constructional point of view. Moreover, the change in behavior of pH and EC with cement addition is also analyzed. Simultaneously, it also attempted to make a correlation between this two which finally can help to understand the process of peat-cement reactions. From the results, it has been seen that pH and electric conductivity are a good indicative parameter through which the variations of other important parameters can be related. Finally, from the correlation, it is seen that irrespective of all curing days, the electric conductivity increases with increase in pH. However, this increase in EC with pH increment is found to be high at higher percent of cement.

Keywords Organic content · pH · Electric conductivity · Cement

1 Introduction

Peat is an exceptional type of problematic soil whose characteristics varies with a wide range of property difference hence making it a very poor kind of foundation material [6]. Therefore, it has become essential to comprehend the behavior of various properties of the peat so as to venture any constructional activity over it. In peat before processing any activity, few crucial parameters like bulk density, shear strength, void ratio, and compressibility which needed to understand. A number of studies have been done keeping these parameters as a sole concern in understanding the overall

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peat behavior and also from the design point of view. However, apart from this there lie few other parameters like pH and EC which also need a significant attention while discussing or understanding the nature of peat. pH of a soil gives the measure of its acidity, neutrality, or alkalinity in terms of hydrogen ion concentrations in the soil–water system. A hydrogen ion is actually an acid cation which larger in proportion in the solution tells a high acidity in the solution. Peat acidity is highly influenced by the origin of rock, origin of plants, extent of oxygen supply, and concentration of humic acid. The acidity in the peatland occurs through two processes, one by microbial deterioration process and other through cation exchange capacity. The first process, there occurs the breakdown of the fiber, dead parts of roots, and plants by the bacteria and fungi which finally discharge acid solution into nearby zone. However, in the second process, the prevailing occurrence of peat moss (incompletely putrefied rotten plant life) acidifies to its nearby by cation exchange. Apart from this, the large accretion of organic substance, disintegration, and the firm release of acids (humic and fulvic) may be one another cause for low pH in peat. The typical pH value of different types of peat varies from 3.2 to 6.81 [7, 15]. Construction projects in acidic soils zones can be challenging to accomplish. Acidic soil appearing as acid sulfate soils is unconsolidated estuarine clays and muds, similar to gel-like traits and poor load-carrying ability [10]. Constructions or earthworks executed on such constituents may keep on settling or subsiding in a slow and uneven manner. A cautious engineering is vital to avert problems with subsidence, which can make highways to slump and foundations to crack. Electrical conductivity (EC) is the capability of soil in carrying electric current, and it is generally expressed in mircoSiemens (μS/m) per distance. It is generally influenced by many different aspects such as temperature, organic content, pH, cation exchange capacity, and moisture content. Further, there occurs a strong correlation between the texture type and particle size with conductivity. It is observed that minerals changing from clay to sand exhibits from high to low conductivity values, respectively [9]. The literatures reported that regardless of decomposition stage, electric conductivity of peat reduces with increment in organic content [2]. Peat with high stage of decomposition holds more negative charge and high colloidal portion, which increases significantly the electrical conductance [2]. Robert et al. [16] mentioned that the electrical conductivity also varies depending upon the quantity of water seized in soil. Electrical conductance of soil is used in geotechnical engineering for site characterization, further it gives provide useful information for predicting other geotechnical parameters [4].

Moreover, it is seen to be connected with numerous hydraulic properties comprising degree of saturation, water content, pore structure, bulk density [8], and also helps to get idea of hydraulic conductivity [3]. Apart from this, some data have reported that it can measure consolidation [12] and degree of compaction [11] for certain soil categories. Further, micro-scale characterization of soil in examining the anisotropy effects has also done by using electric conductivity [12]. In addition, investigators have endeavored to describe liquefaction susceptibility and structural arrangement of sands using electrical measurements at higher frequencies (i.e., > 1 MHz), with considerate degree of success [1].

Nevertheless, apart from understanding the behavioral aspect of peat, it has also become necessary to utilize peat as with growing civilization and infrastructural development it is no longer remains an option to avoid such kind of soil. Various remedial measures have been adopted to deal with this kind of soil such as excavation-displacement or replacement, vertical drains and preloading, RCC piles, stone columns, light weight foundation system, and chemical stabilization technique [14].

However, out of all these, chemical stabilization/solidification process is a commonly used technique for the remediation of peat soil. In this process, peat soils mixed with a binders (like cement, lime and fly ash) to lower the organic matter content which finally enhances the chemisorption, soil strength through precipitation, physical encapsulation and ion exchange. All through the literatures, the effectiveness of this chemical treatment was been discussed mostly by strength and compressibility criteria. However, there occurs very less record of study where they have discussed pH and electric conductivity criteria. Therefore, considering all the previous history, this present study focuses in analyzing mainly on two aspects. One is considering the importance of discussing pH and EC of peat soil in engineering prospect and other to analyzing its changing pattern after the chemical treatment with use of cement. Further, this study also highlighted the correlation between the pH and EC of cement-treated peat.

2 Material and Methods

2.1 Peat

Peat collected in this study is from two districts in the state of Assam, one is from Cachar and other is from Hailakandi. In Cachar, it is collected from National highway 39 (NH39) locations, and in Hailakandi, it is collected from Kalinagar tea estate (KTE) area. It was noticed that the deposition of peat occurs at a depth of 1–2 m below the ground level and with the mean thickness of its layer is 1.5–6 m. The physicochemical properties of the studied peat are shown in Table 1. The cement

Table 1 Physicochemical properties Indian peat

Parameters	NH39	KTE
Water content (%)	268	600
Organic content (%)	20	36
Specific gravity	2.03	1.9
Fiber content (%)	8.11	77.4
pH	5.1	5.5
Electric conductivity (MicroSimen/cm)	199	204
Degree of humification	H_8-H_{10}	H_1-H_4

Table 2 Chemical composition of ordinary Portland cement

Chemical composition	Amount (%)
Calcium Oxide (CaO)	63.78
Silicon Dioxide (SiO_2)	21.08
Ferric Oxide (Al_2O_3)	3.71
Aluminum Oxide (Al_2O_3)	4.42
Sulfuric Trioxide (SO_3)	2.43
Magnesium Oxide (MgO)	1.6

used for the chemical treatment purpose is of ordinary Portland cement (OPC) of 43 grade. The chemical constituents of the OPC in percentage on a dry weight basis are shown in Table 2. The water used throughout the study is the normal water, except where standard specifications require distilled water.

The pH and EC were evaluated at different percentages (5, 10, 15, 20, and 30%) of cement which corresponds to maximum dry density (MDD)—optimum moisture content (OMC) and with varying curing days (i.e., 0, 7, 14, 28, 60, and 90 days). Further, they were evaluated out by using a pH and conductivity meter, respectively, according to the ASTM D 2976. A 3–5 g of the finely powdered soil sample is mixing with 50 ml of distilled water (having pH~ 6.5–7.5) and is poured into 100 ml beaker. The mixture is then allowed to get stirred for some minutes in electrical stirrer at 110–130 rotations/minute followed by a gentle filtration. The pH and EC meter are calibrated at their respective standard, and finally, readings are taken from the solution.

3 Results and Discussion

3.1 PH and EC of Cement Treated Peat

pH variation with cement content at various curing days is shown in the Fig. 1 a, b. It is seen from the figure that the pH increases with increase in the cement content. The reason behind this increase is due to the hydration of free lime (CaO) that remains in cement releases calcium ion (Ca^{++}) to pore fluid which increases the pH and finally making a basic environment in the solution. A similar variation has been informed by Eriktus et al. [5] and Rahgozar and Saberian [17]. However, at advanced curing days, the pH value is found to get decreased. This is actually owing to the fact that at early curing days there occurs the consumption of free lime by the organic matter which leaves no such or very few lime to make any further hydration process. This decrement in the pH value with higher curing days is also mentioned by Taku et al. [18] The highest increment for pH is observed for NH39 is 5.1–12.3, and for KTE is 5.5–10.9, which tells that as with organic matter increment in the soil, the extent of pH increment got reduced.

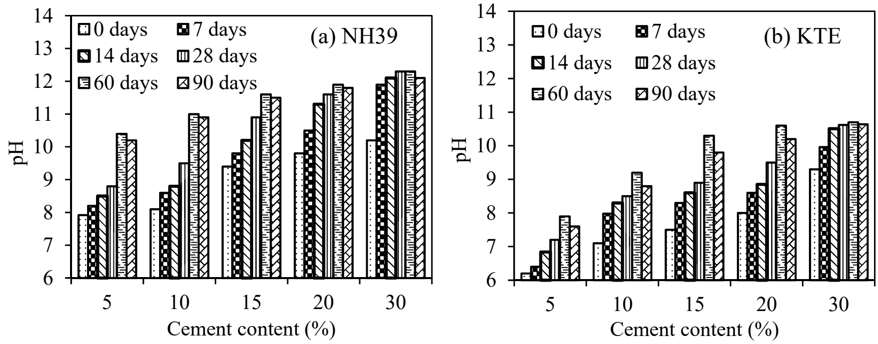

Fig. 1 pH variation with cement content at various curing periods

Figure 2 a, b shows the variation of EC with cement content at different curing periods. It is observed that for both the peats EC increases with increase in the cement content. This increase is due to the effect of calcium and hydroxyl ions (Ca^{2+} and OH^{-}) that produced by the dissolution of cement in the soil pore structure. Further, this increase of EC with cement content can be explained by the inverse relation between electric conductivity and organic content. Since, it is well-known fact that with increase in cement organic content decreases so eventually it increasing the EC value. However, the reduction of EC at higher curing days can be explained due to the reason that at advanced curing days there happens the consumption of Ca^{2+} ion in the pozzolonic reaction which finally shortens the resultant ion activity in the soil pore structure [13].

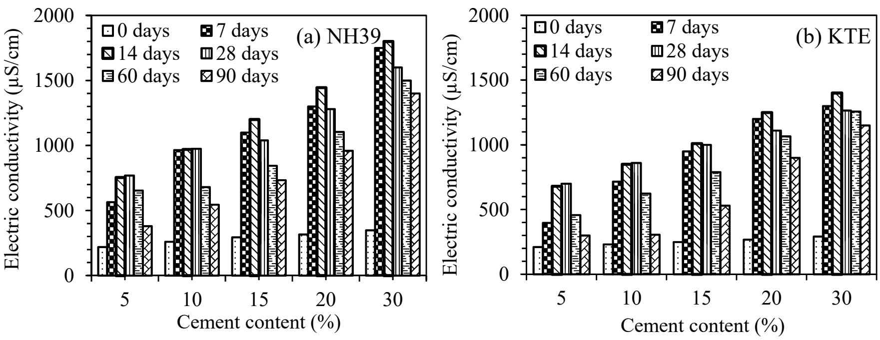

Fig. 2 Electric conductivity variations with cement content at various curing periods

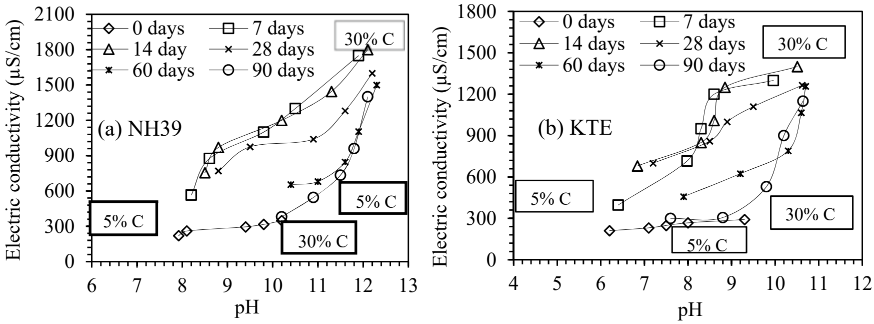

Fig. 3 Relationship between pH and EC with cement content at different curing periods

3.2 Correlation Between pH and EC

Figure 3 shows a typical relationship between pH and electric conductivity of cement-treated Indian peat. It can be seen from the figure that irrespective of all curing days, the electric conductivity increases with increase in pH. However, it is also observed that the relative steepness of the curve goes higher with increasing percentage of cement (>10% C) in both the peats. This indicates a small change in pH brings about a large change of EC.

4 Conclusion

To adequately characterize different types of peat for foundation of structures, it is necessary to accumulate sufficient data regarding soil properties which invariably includes chemical parameters also. Thus, pH and EC of soil are very essential for construction-related issues. The pH of soil is the measurement of its acidity and alkalinity. A low pH (<7) that is acidic soil can cause severe impacts to the environs and to infrastructure. Further, the presence of acid can also bring damage to steel and concrete, gradually abolishing roads, pipes, bridges, and constructions. In expanses before construction where acid sulfate soils are not given due concern, a costly repairs may be needed, or structure must be to be substituted well before the end of its envisioned life period. The need of electrical conductance of soil is quite important in the field of geotechnical engineering for site characterization. Although its direct application has not been found much, but it helps in giving information of prophesying other geotechnical parameters. The improvement in the quality of peat in terms of strength after the cement treatment can be well supported by through pH and EC variation. The generation of alkaline environment due to rise in pH after cement addition kindles largely the dissolution of silica and alumina in the solution finally rendering formation of cementitious gel which held responsible for the development of strength. Further, the increase in EC of the cement-treated peat gives much better ability to store and hold onto cation which itself supports the mechanism where the release of Ca^{++} ion from cement in the solution reacts with soil pozzolans to produce strength enhancing products. Finally, it is seen that regardless of all curing days, the electric conductivity increases with increase in pH.

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