Global Journal of Researches in Engineering: E
Civil And Structural Engineering
Volume 15 Issue 1 Version 1.0 Year 2015
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Effect of pH on Shear Strength Behavior of Granular Soil

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Abstract- In this research, the performances of pH value on shear strength behavior of granular soil have been studied. The shear strength of soil is an important term in most of the foundation engineering problems such as the bearing capacity of shallow foundation, slope stability of dam/embankment and lateral earth pressure on retaining walls. A series of direct shear test were conducted on two types of dry granular soils (taken from Rangpur and Rajshahi areas of Bangladesh) with different pH value (pH=0, pH=3.0, pH=5.0, pH=7.0 and pH=9.0). Hydrochloric acid (HCl) and ammonia (NH4) solution were used to monitor the pH of the solution for about thirty days. In all, 15 specimens of each type of soils were considered for direct shear test with dry condition at a constant density. The specimens were prepared by static compaction with different pH values solution (0, 3, 5, 7and 9) at same void ratio. Experiment result shows that the shear strength increase with increase of pH values of soil.

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GJRE-E Classification : FOR Code: 290899

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I. Introduction

All of the civil engineering structures involve some structural element with direct contact to the soil. The stability of this structures are mainly depends on the stability/strength of contact soil. Granular soil is one of the commonest materials that are widely used in the construction of civil engineering infrastructures, such as earth dams/embankments, roads and so on. The shear strength behavior of granular soil is complexive when they loaded [1]. The variations of the behavior mainly depend on the discrete nature of the particles like shape, size, surface texture, particles distribution and also depend on pH value which was studied in this paper. pH value of soil is decreasing day by day by acid rain, industrial residue, fertilizer, insecticides etc. However there is limited available information in existing literature on shear strength behavior of granular soil for different pH values soil. Considerable researches have been carried out on this purpose (Olukorede M. Osuolale, Olumide D. Falola and Mojeed A. Ayoola (2012) on Effect of pH on Geotechnical Properties of Laterite Soil Used in Highway Pavement Construction) [9], (Rahanuma Tajnin, Tabassum Abdullah, Md. Rokonuzzaman (2014) on Study on the salinity and pH and its effect on geotechnical properties of soil in south-west region of Bangladesh) [10] here shear strength is not considered as important properties of soil but in this paper only shear strength properties was investigated as an important factor on which pH affect.

II. Materials and Equipment

The two types of sandy soil used in this study which address as S-1 (S-1 soil sample has been collected from Tista river, Rangpur of Bangladesh which is locally called domar sand) and S-2 (S-2 soil sample has been collected from Padma river, Rajshahi of Bangladesh which is locally called local sand). Hydrochloric acid (HCl) and ammonia (NH4) solution were used to monitor the pH. The basic properties of two samples are presented in Table 1.

The basic equipments which are used in this study are: (i) Direct shear test device, (ii) Load and deformation dial gauge and (iii) Balance, (iv) pH meter etc.

Table 1 : Basic properties of soil sample S-1 and S-2 (Before contamination)

Basic Properties	Obtained Value	
	S-1	S-2
Grain Size Distribution: Effective size, D_{10} (mm) Diameter corresponding to 30% finer, D_{30} (mm) Diameter corresponding to 60% finer, D_{60} (mm) Uniformity co-efficient, $_{Cu}$ Fineness Modulus, FM	0.33 0.40 0.60 1.82 3.10	0.22 0.26 0.35 1.59 2.50
Specific Gravity	2.64	2.61
Compaction: Maximum dry density, $\rho_{d(max)}$ (gm/cm^3) Optimum moisture content, OMC (%) Void ratio, e	1.63 15.10 0.64	2.59 15.19 0.65

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III. Laboratory Testing

a) Direct Shear Test Program and Procedure

A series of 30 direct shear tests carried out on 2 soil samples referred to as S-1 S-2 (15 tests for each sample). The basic properties of sample specimens were presented in Table 1. Each soil sample (S-1 and S-2) was divided into five portions. Each portion of the soil sample was stored in the big perforated plastic containers labeled A, B, C, D and E. The containers were perforated at the bottom so that the water can drain slowly in order to simulate the actual field condition. The Hydrochloric acid (HCl) and ammonia (NH4) were used to prepare solution that has pH of 3, 5, 7 and 9. The container that was labeled A is uncontaminated while the solutions with pH of 3, 5, 7 and 9 were poured into containers labeled B, C, D and E respectively. The five containers with its contents were then stored for about 30 days in the laboratory. After 30 days the samples were air dried and direct shear tests (3 samples from each container to determining average value) were carried out on them at same density and void ratio. To carry out these tests, a sample of soil is placed into the shear box. The size of the box is used 60 mm diameter and the sample is 33 mm thick. The soil is placed into the box by trimming 3 equal layers which gives void ratio 0.64 for S-1 and 0.65 for S-2. After the specimen is placed in the box, and all the other necessary adjustments are made, a known normal stress σ is to be applied (1.42 psi). Then a shearing force is applied. The normal load is kept constant throughout the test but the shearing force is applied at a constant rate of strain. The shearing displacement is recorded by a dial gauge. The procedure is repeated five times at different normal stresses (2.84, 7.11, 14.23 and 21.34psi) for each time. These results are plotted on a shearing diagram where σ (normal stress) is the abscissa and τ (shearing stress) the ordinate. The slope of the line gives the angle of internal friction (ϕ°) and the intercept on the ordinate gives the apparent cohesion (c psi). The shear strength is determined by using $\tau = c + \sigma \tan(\varphi)$.

IV. Results and Discussions

a) Presentation of Test Result and Discussion

All the specimens were tested under dry condition. The results of the shear strength are presented in Table 2 below for each sample. The shear strength increases with increase in pH value. Figure 1 and 2 represents the shear strength versus pH values relationship and from this figure it is investigated that the shear strength increases with increase in pH value.

Table 2 : Shear strength variation chart of both sample

Sample		Shear strength (psi)				
		Con. A (pH=0)	Con. B (pH=3)	Con. C (pH=5)	Con. D (pH=7)	Con. E (pH=9)
S-1	1	2.95	3.09	3.15	3.48	3.60
	2	2.97	3.04	3.13	3.60	3.65
	3	3.01	3.08	3.17	3.56	3.59
	Average	2.98	3.07	3.15	3.55	3.61
S-2	1	2.79	2.84	2.99	2.99	3.25
	2	2.75	2.77	2.94	3.08	3.52
	3	2.74	2.82	2.86	2.92	3.45
	Average	2.76	2.81	2.93	3.00	3.41

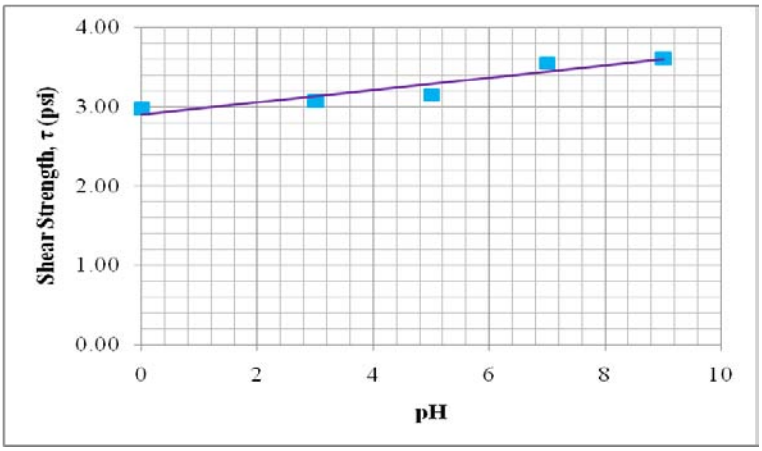

Figure 1 : Shear strength Vs. pH values of S -1

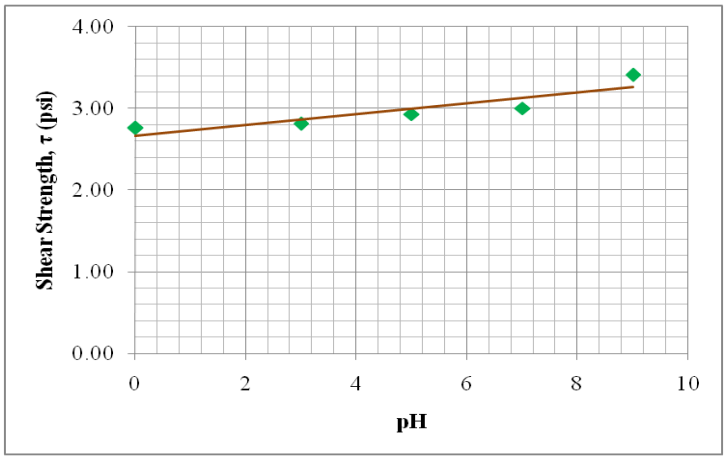

Figure 2 : Shear strength Vs. pH values of S -2

V. Conclusions and Recommendation

On the basis of literature test carried out following concluding remarks are made:

a) Shear strength of granular soil is increase with increase of pH value. So if we want to increase shear strength of acidic soil we have to increase pH value. The most common amendment to increase soil pH is lime ($CaCO_3$ or $MgCO_3$).
b) Farther investigation is required for others type of soil.

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