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Study on Consolidation and Correlation with Index Properties Of Different Soils in Manipur Valley

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Abstract:- It is essential to know the rate of compression of clay for design purposes. Determination of the value of coefficient of consolidation c_v which gives the rate at which compression of soil layer takes place can be done by conducting routine one-dimensional consolidation tests. Since this test is time consuming, it is desirable to predict the value of c_v by correlating with some simple index property, especially for preliminary assessment. From literature, it can be seen that researchers have attempted to correlate c_v with various index properties like liquid limit (Lambe and Whitman, 1979), plasticity and liquidity index (Carrier, 1985),void ratio at the liquid limit and in situ effective overburden pressure (Raju et al., 1995), shrinkage index (Sridharan and Nagaraj, 2004) etc. To obtain a correlation of c_v with index properties for the soil of Manipur, routine one-dimensional consolidation tests were conducted on five different types of soils collected from different places of Manipur. From the present experimental study on undisturbed soil specimens, it is found that c_v has a better correlation with the liquid limit.

Keywords:- liquid limit, plasticity index, shrinkage index, coefficient of consolidation, overburden pressure.

I. INTRODUCTION

Settlements in deep deposits in soft clay constitute an engineering challenge in construction of buildings, road embankments, flood control levees, dykes and dams. For improvement of soft soil or the construction of building foundations or embankments, it is essential to know the rate of compression of this soil. This can be done by conducting routine one-dimensional consolidation tests from which the values of compression index C_c and coefficient of consolidation c_v can be evaluated. This process is time consuming and there is a need to predict long term settlement with a high degree of accuracy in short duration of time by correlating these long process for determination of consolidation test of soil with some other simple properties tests. Due to time constrains, emergency of the project as well as for a better comparison, several correlations are widely used while preparing geotechnical investigation report. Carrier (1985) has made an early attempt to predict coefficient of consolidation, cv (in m^2/s) as given by the equation,

$$C_V= [9.09\text{x}10^{-7}(1.192+ACT^{-1})^{6.993}(4.135I_L+1)^{4.29}]/[I_p(2.03I_L+1.192+ACT^{-1})^{7.993}],$$

where, ACT=Activity, I_L=Liquidity index, I_P=Plasticity index and it can be observed from above equation, the coefficient of consolidation (c_v) is inversely proportional to the plasticity index. Raju (1995) proposed an equation to predict coefficient of consolidation, c_v (in cm^2/s) for a normally consolidated clay in terms of the void ratio at the liquid limit (e_L) and the in situ effective overburden pressure, σ_v (kPa), given as $c_v=[1+[e_L(1.23-0.276\log\sigma_v)/e_L]]*[[1/\sigma_v'^{(0.353)]*}10^{-3}]]$, Sridharan and Nagaraj (2012) have brought the role of plasticity properties in controlling the compressibility characteristics. They have shown that shrinkage index has a better correlation with compressibility characteristics than the plasticity index or liquid limit of soils given by the equation cv= $[3/(100(I_s)^{3.54}]$, where, c_v= Coefficient of consolidation in m^2/sec; I_s= Shrinkage index. Asma et al.,(2011) have proposed a relation between coefficient of consolidation and liquid limit of undisturbed silty clay of Middle and South Iraq is $c_v= 4258\ w_L^{(-1.75)}$,where, w_L= Liquid limit of soil. Solanki (2011) study compressibility characteristics for locally available highly plastic clay for Surat City and Suda treated with different percentages of rice husk and found that coefficient of consolidation has a better correlation with plasticity index shown in the equation $(c_v) = 7.7525\ I_p^{-3.1025}\ cm^2/sec$. It is inferred from the works of various researchers that there are varying opinions on the correlation of c_v with the different plasticity properties of different clays. The paper is an attempt to find suitable correlation of c_v with the plasticity property of the soil found in Manipur.

The soil cover of Manipur constitutes mainly of the red ferrogenous soil in the hill area and the alluvium in the valley. A study of soil profiles available from soil investigation reports in Imphal area, the capital of Manipur show that clay of soft to medium stiff consistency form the major top strata up to 5 to7 m.

This indicates that for large projects consolidation is one of the criteria influencing design. There is very little literature available on engineering properties of soil of Manipur excepting the available soil investigation reports. In this study, five undisturbed samples of clay from different places (Lamphelpat, Keithelmanbi, Singjamei, KeiraoWangkhem and Moirang) of Manipur were used to predict coefficient of consolidation by correlating with some of their index properties.

II. MATERIALS USED

Manipur is a state situated in North-Eastern part of India. Out of total area, about nine-tenth constitute the hills which surround the remaining one-tenth valley. The soil formation in this region mainly consists of soft clays and soft clay with organic matters in low lying areas which have now filled up. It was expected that the value of settlement is high in these places considering the soft nature of clay and high compressibility of the soft clay in comparison to any other type of soil. Locally available five different types of clayey soil including one organic clay soil were used for the test. The descriptions of the sites are given in Table 1.The undisturbed block soil samples of size 300×400×300 mm^3 were collected from the depths of around 1.5 m to 1.75 m from five locations in the valley and near the hilly areas shown in Fig.1. Laboratory investigations were carried out on the soil samples to find their basic index properties.

Table 1: Descriptions of Soil Samples

Notation	Location	District	Depth of soil collection (m)	Description of Area	Soil Description
S-L	Lamphelpat	Imphal-West	1 m	Lake	Blakish grey
S-K	Keithelmanbi	Senapati	1.75 m	Hilly	Yellow Clay
S-S	Singjamei	Imphal-East	0.8 m	Valley	Greyey Clay
S-KO	Keirao Wangkhem	Imphal-East	1.5 m	Hilly	Blakish grey
S-M	Moirang	Bishnupur	1 m	Valley	Blakish grey

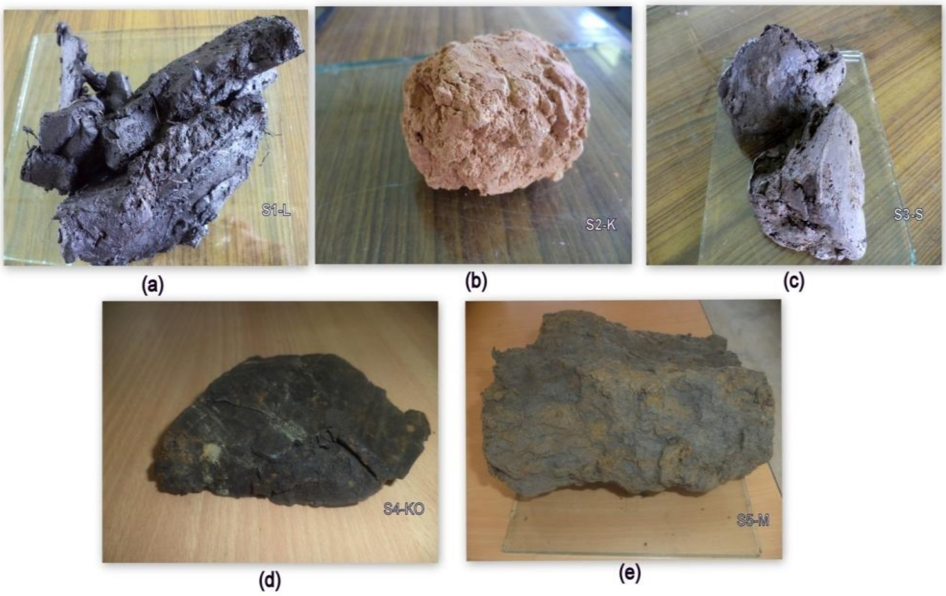

Fig. 1: Five Samples (a) S1-L (b) S2-K (c) S3-S (d) S4-KO and (e) S5-M

III. TESTING PROCEDURE

Various tests were carried out in the laboratory for finding the index and other important properties of five different types of soils collected from different places of Manipur during the study. The details of these tests are given in the following sections. All the geotechnical properties were tested based on IS code specifications.

3.1. Water Content: The natural water content determination is obtained by oven drying method as specified by the IS Test Method IS: 2720 (Part II)-1973.

3.2. Specific Gravity: The specific gravity of the soil has been determined using the density bottle method, as per IS: 2720-(part III section I, 1980).

3.3. Grain Size Distribution: Sieve analysis has been conducted as per IS: 2720 (Part IV 1965).
3.4. Liquid Limit: The test has been carried out using the standard Casagrande liquid limit apparatus as per IS: 2720-(PartV-1965).
3.5. Plastic Limit: The plastic limit of the soil specimens was determined by the rolling thread method as outlined in the IS: 2720 (Part 5)-1985.
3.6. Shrinkage Limit: The shrinkage limit of soil specimens was determined according to Indian standard code for a shrinkage factor IS: 2720 (Part VI) - 1972 of soils by the mercury method.
3.7. Plastic Limit: The plastic limit has been determined according to the IS: 2720- (Part V-1970).

3.8. One-Dimensional Consolidation: One-dimensional consolidation tests were performed by standard floating ring consolidometer with stainless steel rings, 60 mm in diameter and 20 mm high according to IS: 2720 (Part 15)-1986. One-dimensional consolidation tests were performed on five undisturbed samples in standard floating ring consolidometer with stainless steel rings, 60mm in diameter and 20mm high according to IS: 2720 (Part 15)-1986 (Reaffirmed 2002).The test was continued with applied stress of 10, 20, 40, 80, 160, 320, 640 and 1280kPa. For each load increment reading was taken using a time sequence of 0.1, 0.25, 1, 2.25, 4, 6.25, 9, 12.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225, 256, 289, 324, 361, 400, 500, 600 and 1440 minutes. Each specimen was loaded to a stress of 640kPa and later unloaded with a load decrement ratio of one-fourth of the preceding load up to a 10kPa. After unloading the specimen was again reloaded with an increment of four times the preceding load. Each specimen was loaded up to a maximum load of 1280 kPa. This maximum load is then kept for another 15 to 25 days until the compression ceased to a value for determination of creep and the reading were taken after every 24hrs. The time sequences were used to plot the change in thickness of specimen against logarithm of time for determination of co-efficient of consolidation for each load increment as shown in Fig.2.

Fig. 2: Three loading gang Consolidometer (Oedometer)

IV. TEST RESULTS

The properties of soils were tested for water content, specific gravity, liquid limit, plastic limit, soil classification, percentage finer ,activity and consolidation (odometer) test as per relevant Indian Standard code specification and the results are reported in Table 2.

Table 2: Details of Index Properties of Soils Used

Sample	S1-L		S2-K	S3-S	S4-K	S5-M
Location	Langol		Keiithelmanbi	Singjamei	Keirao	Moirang
Soil Description	Black organic clay		Yellow Clay	Grey Clay	Blackish grey	Blackish grey
Water Content w (%)	86		35.29	52.17	30.9	30.2
Specific Gravity G_s	2.48		2.77	2.7	2.78	2.71
Liquid Limit W_L (%)	88		58.65	76.2	62.1	52.4
Plastic Limit WP (%)	67.77		34.56	25.55	29.14	28.87
Shrinkage Limit W_s (%)	25.16		25.80	24.90	25.30	25.00
Plasticity index I_p (%)	40.23		24.09	50.65	32.96	22.53
Shrinkage index I_s (%)	62.84		32.85	51.30	36.80	30.4
Activity	0.657		0.536	0.675	0.978	1.07
Grain size Distribution (%)	Sand	0.01	5.11	0.27	1.55	11.71
	Silt	29.65	53.69	24.73	64.75	59.28
	Clay	70.34	41.00	75.00	33.70	29.00
Soil Classification	CH		MH	CH	MH-CH	MH-CH

4.1 Consolidation Test Results

From consolidation test results, the coefficient of consolidation (c_v) value was determined by Casagrande's method. From Table 3 it is observed that the compressibility of S1-L is the highest. This is expected to the organic content of the soil. Sample S5-M is found to be the least compressive of soils tested.

Table 3: Consolidation Parameters

Parameters	S1-L	S2-K	S3-S	S4-KO	S5-M
Water Content (%)	76	35.29	52.17	30.9	30.2
Initial Void Ratio E_0	1.77	0.707	1.5	0.96	0.71
Pre-Consolidation Pressure σ'_P (kN/m^2)	70	180	160	80	160
Compression Index C_c	0.747895	0.244034	0.257034	0.258915	0.14537
Co-efficient of Consolidation C_v (m^2/Sec)	1.02 E-08 To 6.27E-09	1.32E-07 To 8.84E-08	1.0E-7To 2.73E-08	1.18 E-07 To 4.20E-08	1.25E-07 To 5.95E-08

4.2 Coefficient of Consolidation with Effective Consolidation Vertical Pressure

Fig.2 shows the plot of c_v versus effective vertical pressure (σ'_v) on log-log plot for all the five samples. From this plot it is noted that below an effective pressure of 40 kPa the value of c_v are low. Above this effective vertical pressure, c_v values are more or less the same for all the pressure increment applied for soil.

Robinson and Allam (1998) found from their studies on the response of c_v to σ'_v increase in clays that it is governed by the mechanical and physicochemical factors that govern the compressibility. They have concluded that the increasing behavior of c_v toσ'_v due to the compressibility of such soils being governed by mechanical factors, and the opposite behavior for soils whose compressibility behavior is controlled by physicochemical factors.

Sridharan and Nagaraj (2004) observed from their studies on c_v of remolded soils that c_v values are relatively higher for less plastic than for more plastic soils, through their liquid limit is nearly the same. The author explained that, for a normally consolidated soil, the soil particles become more oriented with increase in effective consolidation pressure and for more plastic soil, the diffuse double layer repulsive forces mobilize and offer more resistance to compression (both rate and amount). For less plastic soils whose compressibility behavior is governed mainly by mechanical forces, as the consolidation pressure increases, the gravitational forces increase and over ride the little repulsive pressure at the particle level in retarding the compression of soil, and hence, the increase in the rate of compression of the soil, i.e., an increase in c_v with pressure.

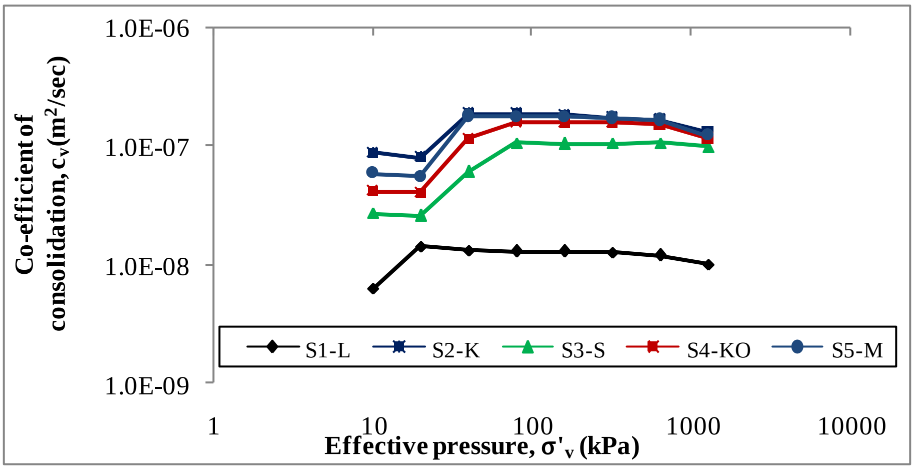

Fig. 3: Coefficient of Consolidation Vs. Effective Pressure

4.3 Correlation of Coefficient of Consolidation with Index Properties

The values of the c_v of five different soils obtained from the experimental results are correlated with index properties viz. liquid limit, plasticity index and shrinkage index to check which one fits the best. Coefficient of correlation 'R^2', determined graphically using Microsoft Excel spreadsheet, is used as evaluation criteria to check the best fits of the curves. Figs. 4, 5, and 6shows the correlation of coefficient of consolidation with liquid limit, plasticity index and shrinkage index along with their coefficient of correlation.

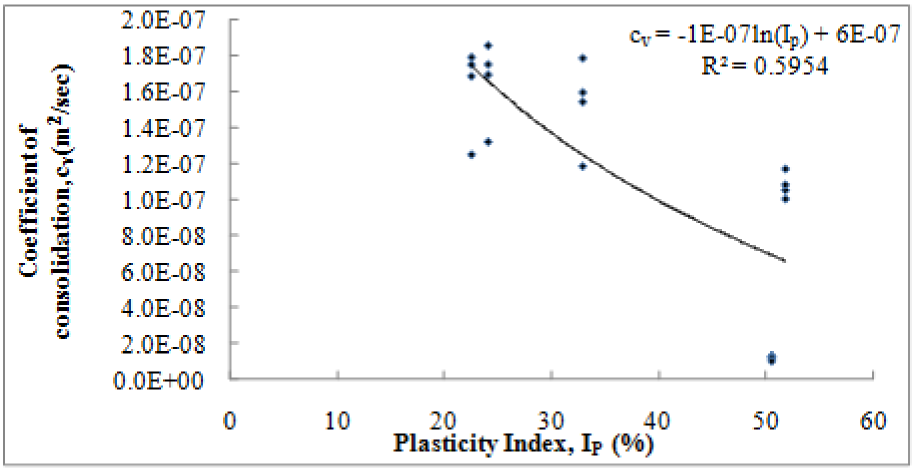

Fig.4: Relationship between Plasticity Index and Coefficient of Consolidation

From these figures it is observed that scatter is most in the correlation of c_v with plasticity index. It is also observed that better correlation exists between c_v and shrinkage index (liquid limit-shrinkage limit) as compared with the plasticity index. However, coefficient of consolidation correlates the best with liquid limit compared to the plasticity index or shrinkage index for the soils under study.For the soils under study, the c_v can be correlated with liquid limit by the equation

c_v= $-4x10^{-9}w_L+4x10^{-7}$, Where, c_v= coefficient of consolidation in m/sec, and w_L= liquid limit

From this study it is clear that for undisturbed soil samples, among the correlation of c_v with index properties correlation of c_v with liquid limit is a better correlative parameters in comparison with shrinkage index and plasticity index.

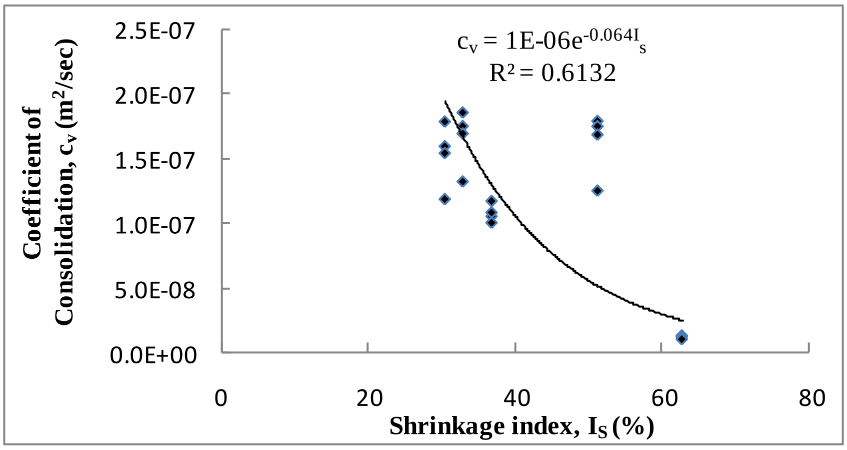

Fig. 5: Relationship between Shrinkage Index and Coefficient of Consolidation

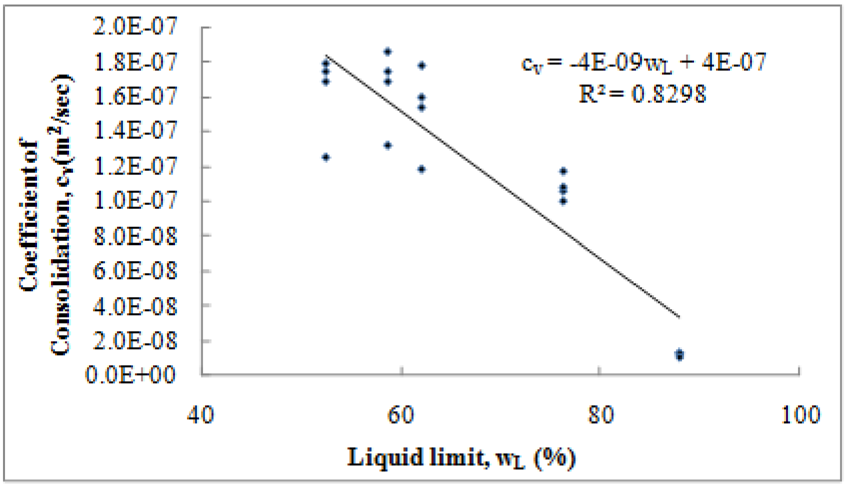

Fig. 6: Relationship between Liquid Limit and Coefficient of Consolidation

V. CONCLUSION

From the experimental results the specific gravity varies between 2.48 to 2.78, liquid limit values are 52.4% to 88%, plastic limit values between 25.55% to 67.77% and the shrinkage limit values are ranging between 24.90 %to 25.80% , consolidation tests void ratio varies between 0.707 to 1.77 and coefficient of consolidation are between 1.0E-7 - 2.73E-08 to 1.32E-07 - 8.84E-08 for five selected samples. An attempt has been made to correlate the variations in the values of c_v and index properties of the soils. The conclusion of the study for the prediction of c_v by correlating with some simple index properties viz. liquid limit, plasticity index and shrinkage index, it is concluded that c_v correlates better with liquid limit of soil.

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