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ESTABLISHING RELATIONSHIP BETWEEN COEFFICIENT OF CONSOLIDATION AND INDEX PROPERTIES / INDICES OF REMOULDED SOIL SAMPLES

Prof. Guruprasad Jadhav

[1]*Dept. of Civil Engineering, Parvathi Bai Genba Moze College of Engineering Wagholi, Pune Maharashtra, (India)*

ABSTRACT

Coefficient of consolidation of soil sample is necessary in time rate settlement calculation. To obtain coefficient of consolidation (Cv) it is necessary to conduct the one-dimensional consolidation test. However, it takes a long time to measure the value of Cv in laboratory. Hence, in this study an attempt is made to establish the relation between Cv with some index properties/indices of soil. Therefore this study will help in the determination of Cv from index properties/indices of soil without conducting one-dimensional consolidation test. The experimental work is carried out in laboratory on twenty different soil samples (Liquid limit range from 20 to 70) which is collected from different location of Bagalkot district of Karnataka state. For consolidation test, soil samples are remoulded at their respective liquid limit and it is consolidated to gradually increment of stress from 0.05kg/cm2 to 1.6kg/cm2. Regression analysis carried out between index properties/indices and Cv value obtained from laboratory using Microsoft Excel software. Analysis reveals that, Cv value has good correlation with some index properties/indices and developed models estimates the reasonable Cv value.

Keywords: Coefficient Of Consolidation, Regression Analysis, Liquid Limit, Shrinkage Index.

I INTRODUCTION

When a soil mass is subjected to compressive force, like all other materials, its volume decreases. The property of the soil due to which a decrease in volume occurs under compressive forces is known as the compressibility of soil. The compression of soils can occur due to one or more of the following causes.

1. Compression of solid particles and water in the voids.
2. Compression and expulsion of air in the voids.
3. Expulsion of water in the voids.

Compression of solid particles is negligibly small. Compression of water in the voids is also extremely small, as the water is almost incompressible in the range of stresses involved in soil engineering. Therefore, the compression due to the first cause is not much significant.

Air exists only in partially saturated soils and dry soils. The compression of the air is rapid as it is highly compressible. Further, air is expelled quickly as soon as the load is applied. However, the compression due to

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the second cause is not relevant for saturated soils.

When the soil is fully saturated, compression of soil occurs mainly due to the third cause, namely, expulsion of water. Only this cause is relevant.

The compression of a saturated soil under a steady static pressure is known as consolidation. It is entirely due to expulsion of water from the voids. It is similar to the action of squeezing of water from a saturated sponge under pressure. The soil behaves as a saturated sponge. As the consolidation of soils occurs, the water escapes. The solid particles shift from one position to the other by rolling and sliding and thus attain a closer packing. It is worth noting that the decrease in volume of soil occurs not due to compression of solids or water but due to the shifting of positions of the particles as the water escapes. Small volume changes may occur due to bending, distortion and fracture of the soiled particles, but such changes are insignificant in the ordinary range of stresses involved in soil engineering problems. However, bending, distortion and fracture are indirectly responsible for a further decrease in volume due to shifting of particles.

A study of consolidation characteristics is extremely useful for forecasting the magnitude and time of the settlement of the structure. These characteristics are usually described using two well known coefficients. Compression index Cc and the coefficient of consolidation Cv. The coefficient of consolidation (Cv) used to predict required time for a given amount of compression to take place and the compression index (Cc), is directly used for calculation of settlement [1].

Generally the value of Cv is obtained from the laboratory one dimensional consolidation test by means of curve fitting procedures and based on Terzaghi one-dimensional consolidation theory [2]. The routine oedometer test is complex, time consuming and expensive [3] and also this value may not be representative of the soil which experiences the deformation in the field due to various factors such as the inherent assumptions involved in the consolidation theory in the methods for evaluation of Cv from the laboratory consolidation test data and the differences between laboratory testing conditions and those in the field. These aspects are not taken into account during laboratory tests [4].

In view of the complexity of obtaining Cv from a consolidation test any attempt to obtain the same from the correlation with the index properties for preliminary design will be most welcome [3]. In the present study an attempt is made to correlate coefficient of consolidation with index properties and to obtain a correlating equation for the same.

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II MATERIALS AND METHODS

2.1 Experimental Work

Twenty soil samples were tested, that have been taken from different sites in Bagalkot region of Karnataka state.

2.2 Index Tests

Index properties of soil are properties, which are used to characterize soils and determine their basic properties such as moisture content, specific gravity, particle size distribution, consistency and moisture-density relationships.

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Table 3.1 Indian Standard codes for Index Properties

Sl. no	PROPERTY	I S CODES
1	Specific gravity	IS 2720 (part III)
2	Atterberg limits Liquid limit % Plastic limit % Shrinkage Limit %	IS 2720 (part V)
3	Grain size distribution Gravel, % Coarse Sand, % fine sand, % Silt &Clay,%	IS 2720 (part IV)

2.3 Consolidation test

Conventional oedometer tests were carried out for determination of coefficient of consolidation. For this purpose a standard and conventional oedometer apparatus having brass ring, 60mm in diameter and 20mm height was used. Two saturated porous stones and filter paper were assembled at top and bottom of the specimen. Then vertical load was applied using loading device. Other details of the test were performed in general accordance with the procedure described in IS: 2720 part 15, 1985.

2.4 Preparation of the specimen

Substantial characteristics and initial different structural conditions of the soil samples are two main factors affecting on the consolidation. For a soil sample, substantial or inherent characteristics could be presented quantitatively by plasticity indices and specific gravity and other properties. Therefore in order to taking into account of these two main factors, conventional one dimension consolidation tests were conducted on each soil samples. To do this, about twenty test specimens were prepared and tested. The specimens with initial water content of liquid limit had slurry state and were filled in the fixed ring, taking care to prevent over topping. Filter papers were placed between specimen and a saturated porous stone to prevent from movement of particles into the porous stone and sample was allowed for double drainage.

2.5 Load application

After trimming top of the specimens and displacement of the upper porous stone and filter paper, the setting load (about 5 kPa) was applied and the setup was left for 24 hours for fully saturation of the specimen. Other procedures were made according to the standard test method. Then load increment from 5kpa to 160kpa was applied .The corresponding deformations in the dial gauge were noted in the time intervals as required for square root time fitting method. Then a graph of time verses dial gauge for a particular loading was plot and Cv

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was determined adopting square root time fitting method. Same procedure was fallowed for all twenty specimens.

Fig 2.5.1 Consolidation setup

III RESULT AND DISCUSSION

3.1 General

In the present study, an attempt is made to correlate the coefficient of consolidation and index properties of remoulded soil sample. For this, consolidation test as well as index properties tests had been conducted on twenty soil samples. The obtained values of index properties are used to predict coefficient of consolidation.

Analysis and discussion of the test results have been done in this chapter and they are in the following order.

- Simple linear regressions between coefficient of consolidation and index properties of twenty remoulded soil samples.
- Multiple linear regressions between coefficient of consolidation and index properties of same twenty remoulded soil samples.

3.2 Regression Analysis

Regression analysis is a statistical technique for modeling and investigation the relationship between two or more variable. A variable whose value is predicted is called dependent variable. A variable used to predict the value of dependent variable is termed as independent variable.

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3.3 Simple linear regression of coefficient of consolidation and index properties of twenty remoulded soil samples

Simple Linear Regression Analysis (SLRA) has been carried out to develop the correlation between individual soil property and coefficient of consolidation value. SLRA can be carried out using standard statistical software like Data Analysis Tool Bar of Microsoft Excel in order to derive the relationship statistically.

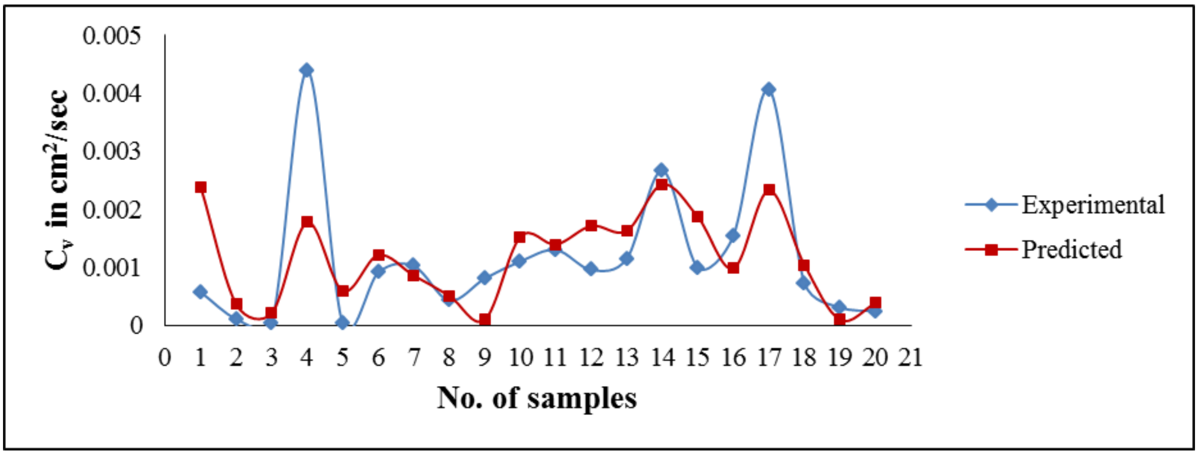

Fig 3.3.1 Comparison between experimental and predicted Cv value for liquid limit

An attempt is made to correlate the liquid limit and coefficient of consolidation (Cv) values of experimental results of soil sample collected for investigation, it is shown in Fig 4.1 and it is observed that the coefficient of consolidation (Cv) value decreases with increase in liquid limit. Fig. 4.2 shows the comparison of experimental and predicted values of coefficient of consolidation. From SLRA correlation coefficient (R2) is found to be 0.4081. It represents there is no significant relation exist between these two parameters to predict Cv from liquid limit.

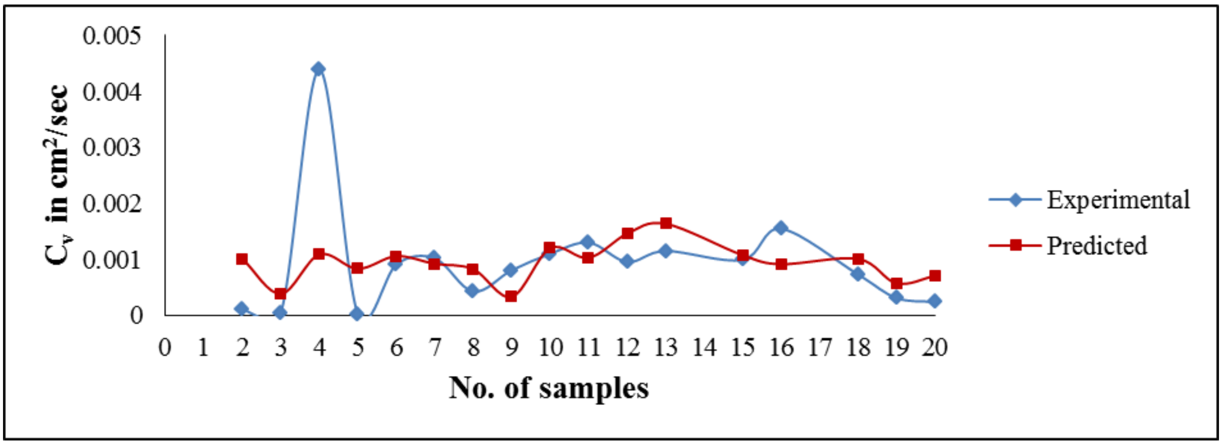

Fig 3.3.2Comparison between experimental and predicted Cv value for plastic limit

Seventeen test data are considered to correlate coefficient of consolidation with plastic limit, and a new linear correlation is derived. Test data of sample 1, 14 and 17 are not considered because these samples are non plastic in nature. Fig 4.3 shows correlation between Cv value and plastic limit and the correlation coefficient (R2) obtained is 0.0179. Fig 4.4 shows the comparison between experimental and predicted Cv value for plastic limit and it is observed that the Cv value has large variation with the plastic limit therefore, correlation is poor

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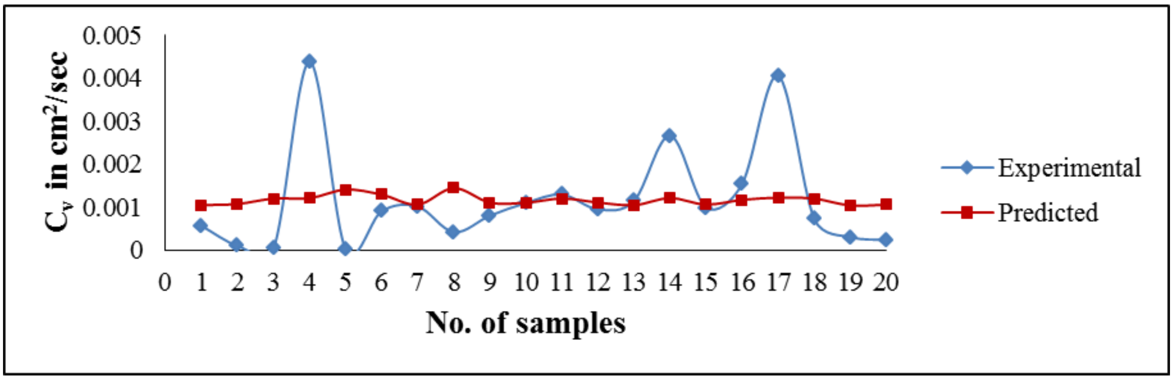

Fig 3.3.4. Comparison between experimental and predicted Cv value for shrinkage limit

A new linear correlation is derived for coefficient of consolidation with shrinkage limit using experimental results, as shown in Fig. 4.5. It is observed that correlation coefficient (R2) obtained by using shrinkage limit is 0.0093 and it is also concluded that Cv value increase with increase in shrinkage limit.

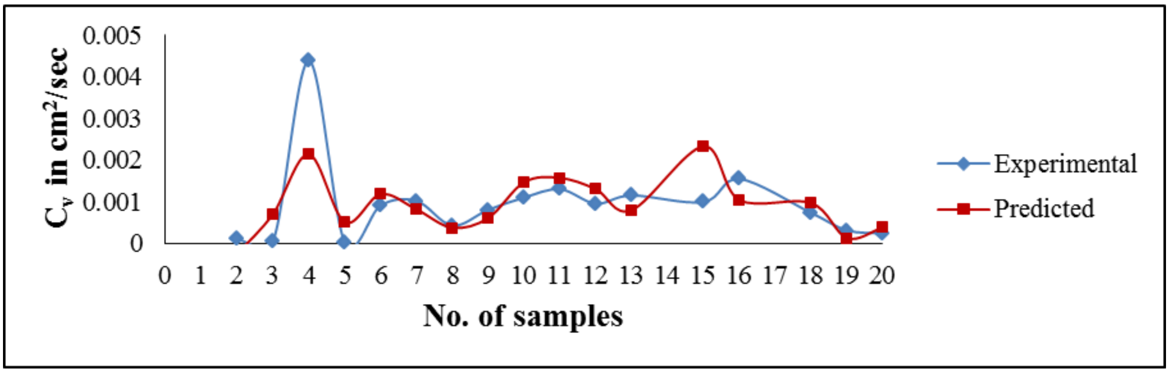

Fig 3.3.5. Comparison between experimental and predicted Cv value for plasticity index

Not considering sample no. 1, 14, 17 (which are non plastic), a correlation is derived between coefficient of consolidation and plasticity index as shown in Fig. 4.7. It is observed that correlation coefficient (R2) obtained by using plasticity index is 0.67 and it can be concluded that Cv value decreases with increase in plasticity index. Fig. 4.8 shows the comparison of experimental and predicted coefficient of consolidation. From this R2 value it can be conclude that relationship between plasticity index and coefficient of consolidation is better compare to the liquid limit, plastic limit and shrinkage limit.

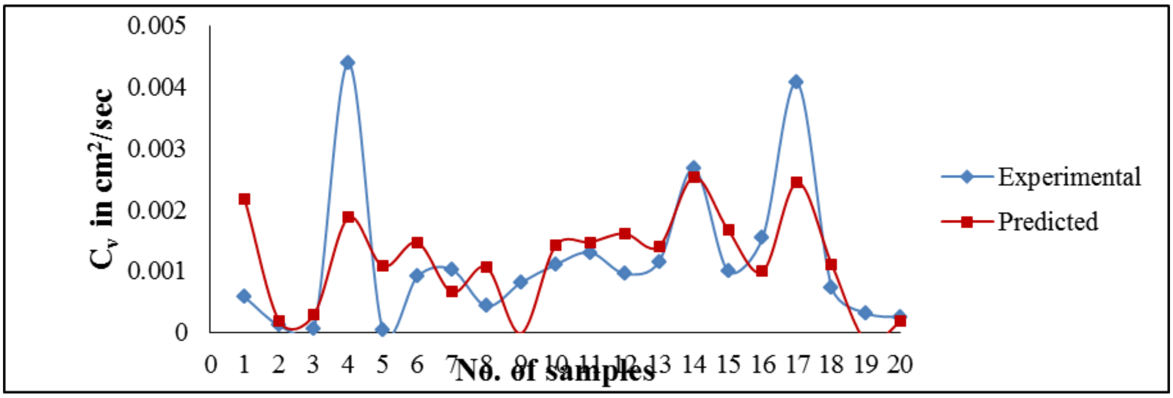

Fig 3.3.6. Comparison between experimental and predicted Cv value for shrinkage index

Using test data of coefficient of consolidation with shrinkage index a new linear correlation is derived. Fig. 4.9

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shows the correlation between coefficient of consolidation and shrinkage index and it is observed that correlation coefficient (R2) obtained by using soil shrinkage index is 0.4272. It can be concluded that Cv value decreases with increase in shrinkage index. Fig. 4.10 shows the comparison of experimental and predicted coefficient of consolidation. This shows that the relationship between shrinkage index and coefficient of consolidation is not significant.

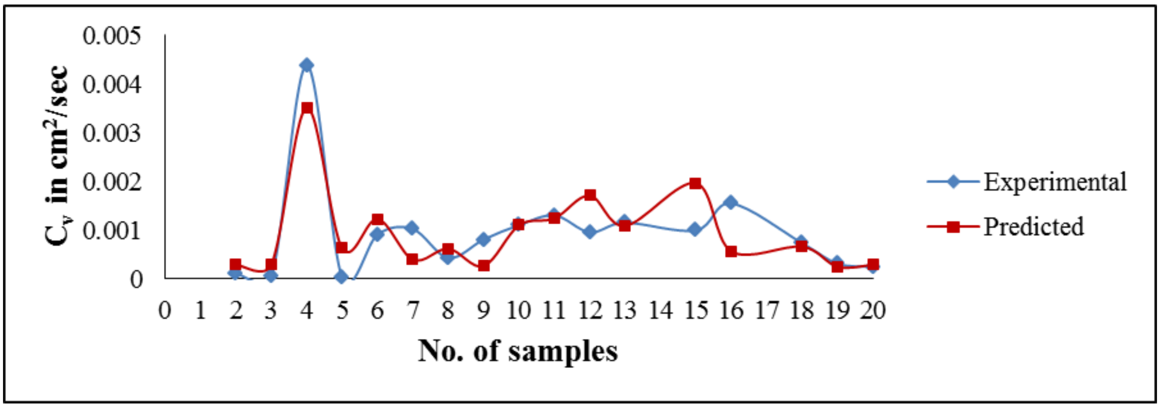

Fig 3.3.7. Comparison between experimental and predicted Cv value for shrinkage index

Seventeen soil data are taken for the analysis, three soil data 1, 14, 17 are not considered because of their non plastic nature. From Fig 4.11 and Fig 4.12 it is evident that the correlation between Cv and shrinkage index is better either than plasticity index or liquid limit, and the correlation coefficient showing better value (R2 = 0.7157) to predict Cv value from shrinkage index

3.4 Multiple linear regression of coefficient of consolidation and index properties of twenty remoulded soil samples

Multiple Linear Regression Analysis (MLRA) has been carried out by considering coefficient of consolidation value as the dependent variable and the rest of soil properties as independent variables. MLRA is carried out using standard statistical software like Data Analysis Tool Bar of Microsoft Excel in order to derive the relationship statistically.

MLRA between Cv value and liquid limit, plasticity index, shrinkage index

Cv = 0.2427/ (LL+Ip+Is) - 0.0015 --------- equation 1 (R2 = 0.482.)

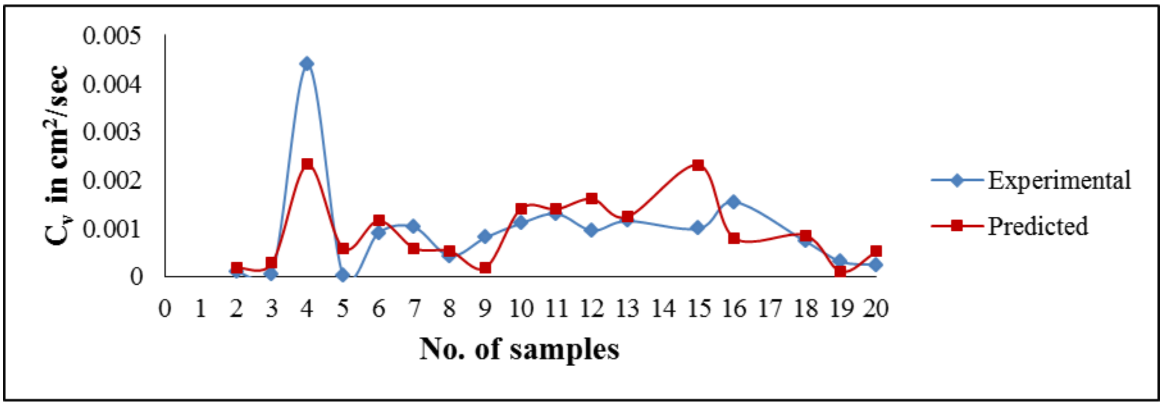

Fig 3.4.1 Comparison between experimental and predicted Cv values

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Sample number 1, 14, 17 are not considered for regression analysis because these soils are non plastic in nature. The coefficient of consolidation value is predicted using the proposed regression model given by above equation (1). The statistical parameters indicate the medium performance by showing the R2 value of 0.482

MLRA between Cv value and plasticity index, shrinkage index

Cv = 0.1139/ (Ip+Is) - 0.0012 ----------equation 2 (R2 = 0.5454)

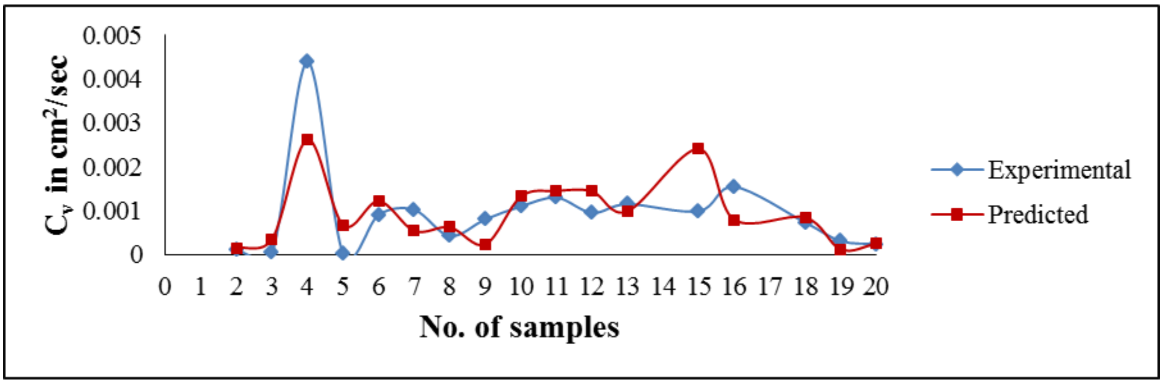

Fig 3.4.2 Comparison between experimental and predicted Cv values

Seventeen soil data are taken for the analysis, three soil data 1, 14, 17 are not considered because of their non plastic nature. The coefficient of consolidation value is predicted using the proposed regression model given by above equation (2). The statistical parameters indicate the medium performance by showing the R2 value of 0.5454. And also it is observed that from fig4.14, the experimental coefficient of consolidation values and the predicted coefficient of consolidation values are not close to each other.

MLRA between Cv value and liquid limit, plastic limit

Cv = 0.0245/ (LL+PL) - 0.0003 ---------- equation 3 (R2 = 0.38)

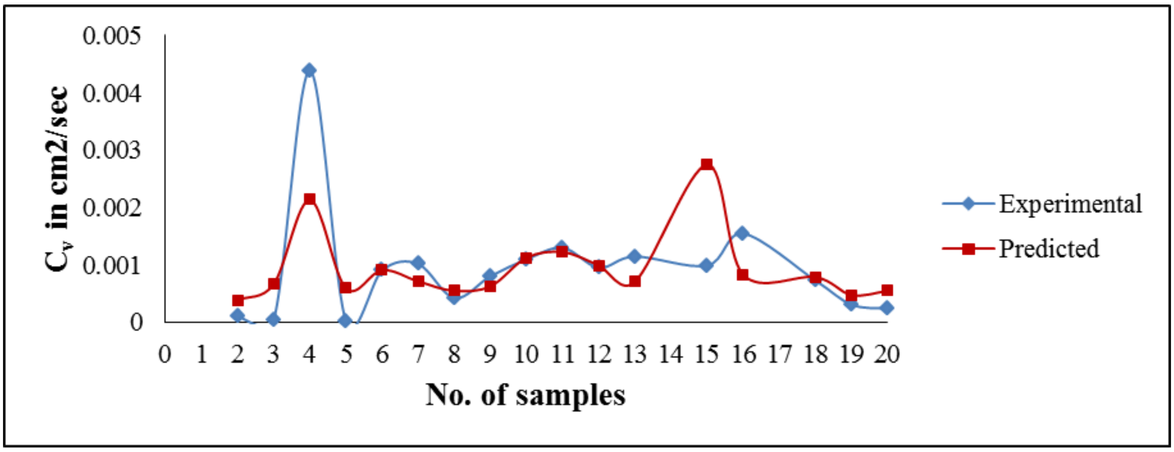

Fig 3.4.3 Comparison between experimental and predicted Cv values

Sample number 1, 14, 17 are not considered for regression because these soils are non plastic in nature. The coefficient of consolidation value is predicted using the proposed regression model given by above equation (3). The statistical parameters indicate the low performance by showing the R2 value of 0.3795. And also it is found from fig 4.15 that the experimental coefficient of consolidation values is not close to the predicted coefficient of consolidation value.

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MLRA between Cv value and liquid limit, shrinkage limit.

Cv = 0.1105/ (LL+SL) - 0.0009 ---------- equation 4 (R2 = 0.2521)

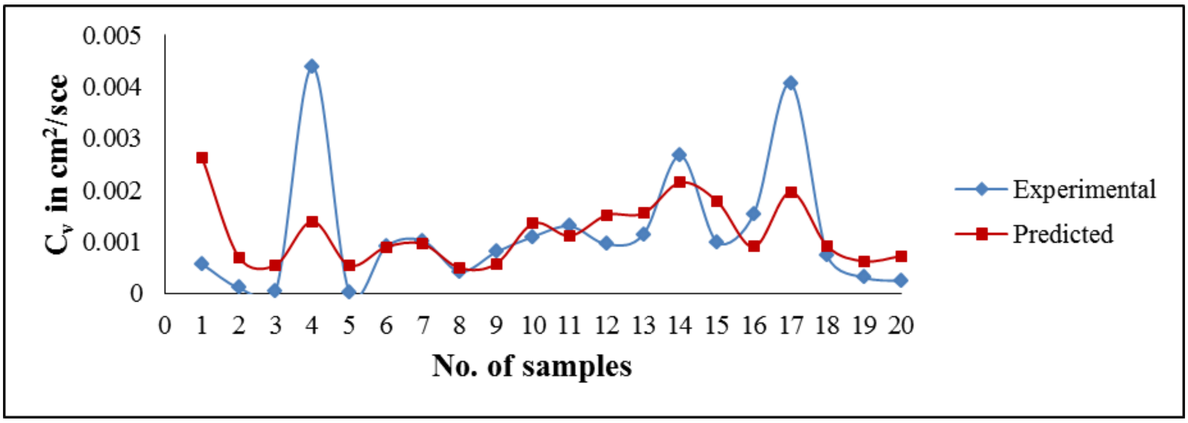

Fig 3.4.5 Comparison between experimental and predicted Cv values

The coefficient of consolidation value was predicted using the proposed regression model given by above equation (4). The statistical parameters indicate the low performance by showing the R2 value of 0.2521. And also it was found from fig 4.16 that the experimental coefficient of consolidation value and the predicted coefficient of consolidation value were not close to each other.

MLRA between Cv value and plastic limit, shrinkage index

Cv = 5.4*PL/(Is)3.54 + 0.0002 ---------- equation 5 (R2 = 0.79)

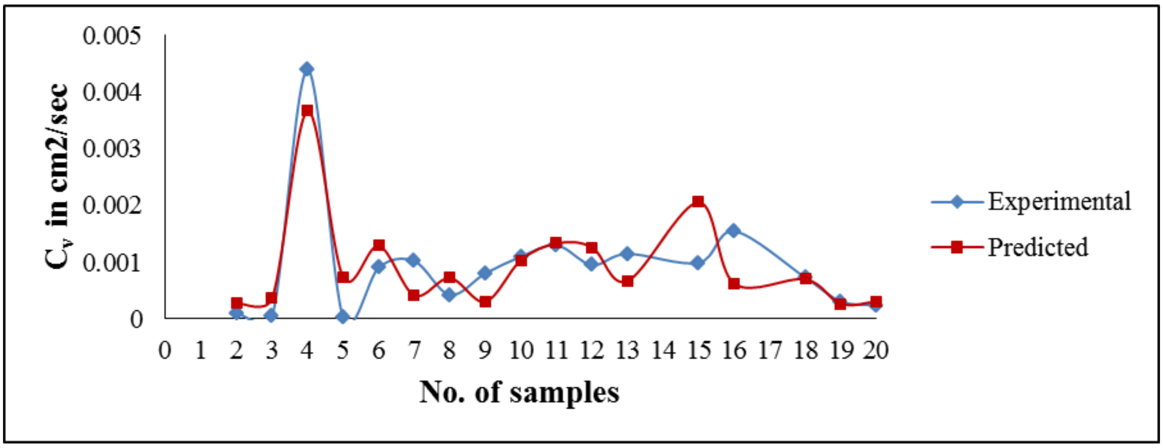

Fig 3.4.6 Comparison between experimental and predicted Cv values

Seventeen soil data are taken for the analysis, three soil data 1, 14, 17 are not considered because of their non plastic nature. The coefficient of consolidation value is predicted using the proposed regression model given by above equation (5). The statistical parameters indicate the good performance by showing the R2 value of 0.79 to predict Cv value from plastic limit and shrinkage index. It is found from fig 4.17 that the experimental coefficients of consolidation values are considerably close to the predicted coefficient of consolidation values

IV CONCLUSIONS

In this study an attempt has been made to correlate the coefficient of consolidation with index properties/ indices. Twenty soil samples of both fine grained and coarse grained are taken and empirical equations has been

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developed using Microsoft Excel.

The following conclusions can be drawn from the experimental and regression analysis of results:

1. The results of coefficient of consolidation (Cv) and index properties tests are interpreted together to infer and to understand the relation between them.
2. The model developed by Simple Linear Regression Analysis (SLRA) for correlating coefficient of consolidation (Cv) with shrinkage index has shown better performance with coefficient of correlation (R2) 0.715.

$$Cv = 128.7/ (Is) 3.54 + 0.0002$$

3. Other models developed by SLRA for correlating coefficient of consolidation (Cv) with Liquid limit, Plastic limit and Shrinkage limit shows less significance to predict the coefficient of consolidation.
4. The empirical relation obtained from MLRA (Cv = 5.4*PL/ (Is) 3.54 + 0.0002) has significant relation to predict coefficient of consolidation value from plastic limit and shrinkage index with correlation coefficient (R2) 0.79.
5. However, in the absence of shrinkage limit data, which is normally not determined in routine testing of soils as compared to plastic limit, the correlation between coefficient of consolidation and plasticity index, although less strong, can be used for prediction purposes.

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