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Establishing relationship between Plasticity Index and Liquid Limit by Simple Linear Regression Analysis

Naveena N[1], Sanjay S J[2], N S Chandanshree[3]
[1]*Dept. of Civil Engineering-B.T.L Institute of Technology*
[2]*Dept. of Civil Engineering-B.T.L Institute of Technology,*
[3]*Dept. of Civil Engineering First-Third University-M S Ramaiah University of Applied Sciences*

Abstract: A Civil Engineer has to deal with soil in their diverse roles. Every civil engineering structure whether it be a building, a bridge, a tower, an embankment, a road pavement, a railway line, a tunnel or a dam, has to be founded on the soil and thus shall transmit the dead and live loads to the soil stratum. Soil is therefore, the ultimate foundation material which supports the structure. Some clay soil, which are extremely hard when dry, can turn into slush having very little shearing strength, when their water content becomes high. Indeed, water is the most important variable controlling the behaviour of fine grained soil. In practice the property of consistency is associated only with fine grained soils, especially clays. In the present study fine grained soils were selected from different locations of Anekal taluk and basic tests were conducted to determine the physical properties of soil. The obtained Plasticity Index (PI) values in the laboratory were compared Casagrade PI values. An equation is generated between Plasticity Index (PI) and Liquid Limit (LL) using Simple Linear Regression Analysis (SLRA) by Microsoft Excel. The PI values obtained from laboratory results, Predicted PI values obtained from SLRA and PI values obtained from Casagrande equation are compared. It is found that all the PI values are in line/parallel and the equation generated is of very good strength.
Keywords: PI, LL, I_p, SLRA, R^2 value, Casagrande equation.

I. INTRODUCTION

Consistency indicates the relative ease with which a soil can be deformed. In practice the property of consistency is associated only with fine grained soil, especially clays. Depending upon the water content, the following four stages or states of consistency are used to describe consistency of a clay soil. i) Liquid state. ii) Plastic state. iii) Semi-solid state. iv) Solid state. The boundary water contents at which the soil undergoes a change from one state to another are called “Consistency Limits”. In plastic state the soil can be remoulded to different shapes without rupturing it, due to its plasticity. If the water content is further reduced, the clay sample changes from the plastic state to the semi-solid state. If the soil does not have plasticity, it becomes brittle. Plasticity index indicates the degree of plasticity of a soil. Clay soil possessing high values of liquid limit and plasticity index are referred to as highly plastic or fat clays and those with low values are described as lean clays. Coarse grained soils cannot achieve the plastic state of consistency and their liquid limit and plastic limit may be said to coincide, that is $I_p = 0$. When the liquid limit or the plastic limit cannot be determined, the plasticity index is reported as NP (Non-Plastic). When LL = PL, I_p is reported as Zero.

Table. 1: Soil classification related to plasticity index.

Plasticity Index, I_p	Soil Description
0	Non-Plastic
< 7	Low Plastic
7– 17	Medium Plastic
> 17	Highly Plastic

Plasticity index is seen to be dependent mainly on the amount and type of clay present in a soil. It is a measure of the cohesive qualities of the binder resulting from the clay content. Also, it gives some indication of the amount of swelling and shrinkage that will result in the wetting and drying of that fraction tested. A deficiency of clay binder may cause ravelling of gravel wearing courses during dry weather and excessive permeability. Amount and nature of clay colloids greatly influence the plasticity. An

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increase in the percentage of clay causes plastic limits to be higher with the moisture content and increases the plasticity number or index.

A. Objectives of the Study

1) Collection of fine grained soils from different locations of Anekal taluk.
2) Determination of physical properties of soil samples.
3) Establishing relationship between PI and LL by SLRA using Microsoft Excel software.
4) Comparison between PI values obtained from laboratory, SLRA, and Casagrande equation.

II. LITRATURE REVIEW

A. Relation Between Liquid Limit and Plasticity Index

The Casagrande plasticity chart showing liquid limit and plasticity index used to classify the soil in 1932 introducing between LL and PI and design A-line.

IP = 0.73*(LL - 20)...Eqn. 1

The linear relationship between LL and PI suggested by Skemption and Norothy in 1953,
IP = 0.689 * (LL - 6.05) and its R^2 value = 0.98 and another study Kaolimite - Bentonite sand mixer in 1964 reported that IP = 0.94 * (LL - 20.61) with R^2 = 0.997. Another relation between LL and PI was introduced by Nagaraj and Jayadeva in 1981, IP = 0.74 * (LL - 8), in confirm that suitable for Casagrande equation.
In 2014, Beshy Keriakose published paper on statistical investigation of relation between LL and PI. Soil sample collected at Cochin marine from different location, in this equation it's very close to Casagrande A-line, IP = 0.63 * (LL - 3.8) and R^2 value is 0.95 as show in Fig. 1.

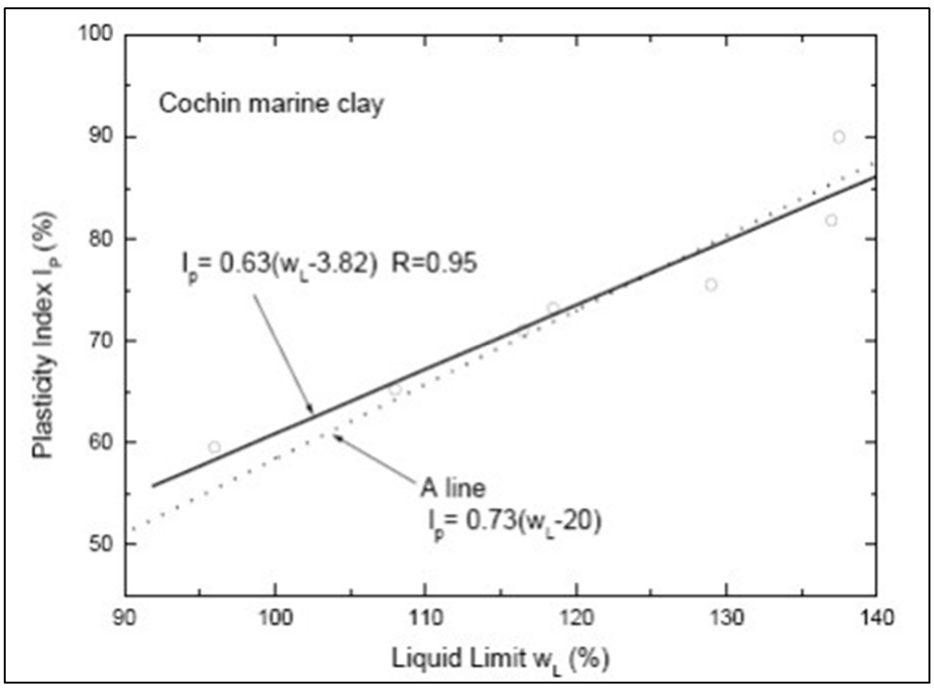

Fig. 1: Comparison of Casagrande A-line and Predicted I_p

III. LABORATORY INVESTIGATION

The list of laboratory tests which were conducted are given below

A. Wet sieve analysis
B. Liquid Limit
C. Plastic Limit

Sample No.	1	2	3	4	5	6	7	8
Gravel, %	0.9	1.8	2.3	2.8	3.0	4.8	5.52	6.9
Sand, %	26.0	36.0	41.0	26.2	45.2	40.2	38.6	44.2
Silt and Clay, %	73.1	62.2	56.7	71.0	51.8	55.0	55.88	48.9
LL, %	63.5	54.8	44.2	41.5	37.7	34.1	30.1	26.8
PL, %	27.1	26.66	25.3	25.3	25.05	24.1	23.5	23.2
PI, %	36.4	28.14	18.9	16.2	12.65	10.0	6.6	3.6
Classification of Soil	MH	CH	CI	CI	CI	ML	CL	ML

Table 2: Consolidated results of laboratory tests conducted on the eight different fine grained soils

IV. DATA ANALYSIS

A. Variation of Plasticity Index (PI) with Liquid limit (LL) for different soil samples

Fig. 1 shows the plot of the variation of liquid limit with plasticity index for the various soil samples considered.

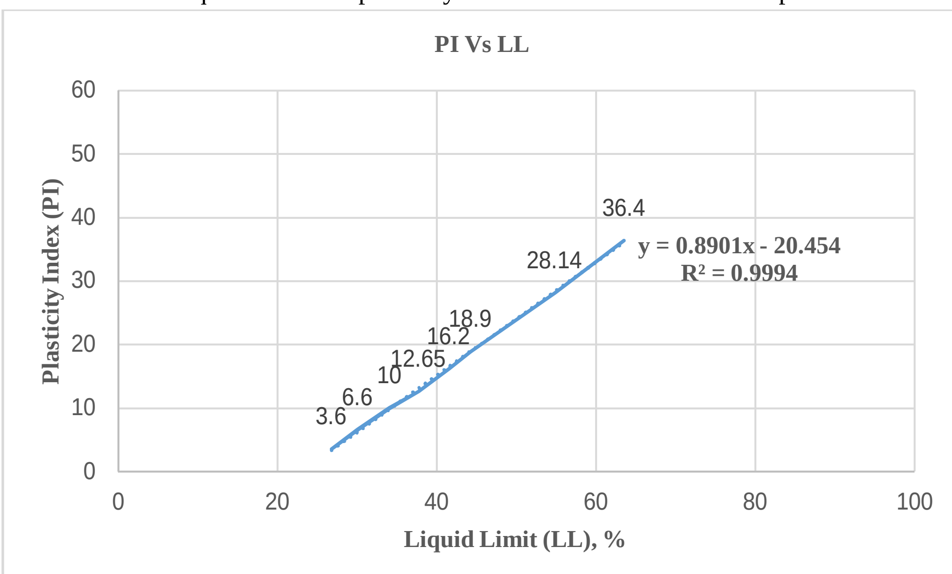

Fig. 2: Correlation between LL and PI

It is seen that as the liquid limit increase, the PI value also increases. In Fig. 3 shown below, the A-line of the Casagrande plasticity chart has been superimposed on the line obtained in the present study.

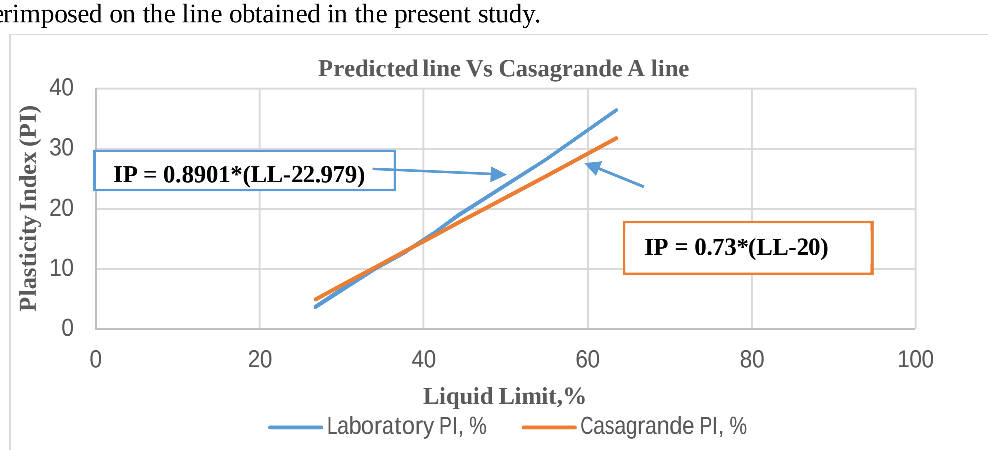

Fig. 3: Comparison between Predicated line and Casagrande A-line

The equation obtained is IP = 0.8901 (LL – 22.9794)...Eqn. 2

From the above figure, it is observed that in correlation between LL and PI, PI is dependent variable and LL is independent variable. In this simple linear regression relation, the standard equation obtained is Y = 0.8901X - 20.454, where Y denotes PI and X denotes LL and its R^2 value is 0.9994. Since R^2 value is more towards 1, it indicates that it is the best fitted linear curve. From Fig 3, it can be observed that the comparison between Casagrande equation and Predicted equation is very close. We know the Casagrande equation is standard equation and is used for classification of the soil. Comparing the results of Casagrande equation IP = 0.73 * (LL - 20) and predicted equation IP = 0.8901 * (LL – 22.9794), both are linear and closely matching with slight variation in LL value. This means that the Predicted equation for the soil samples selected and hence can be validated. Table 3 gives the numerical values for which the plots are drawn.

Table 3: Values of Predicted and Casagrande PI

Laboratory PI, %	Casagrande PI, %
36.4	31.755
28.14	25.404
18.9	17.666
16.2	15.695
12.65	12.921
10	10.293
6.6	7.373
3.6	4.964

V. DISCUSSION AND CONCLUSION

A. The relation between LL &PI by using SLRA method, predicted equation is IP = 0.8901 * (LL – 22.9794). It is very close to Casagrande equation.

B. Also when the PI (i.e. obtained, modified and Casagrande) for the various samples were compared, it was found to be parallel for majority of the soil samples. Hence it can be said that the predicted PI equation can be used for all types of soil.

C. The mathematical model depends on accuracy of laboratory results and independent variables.

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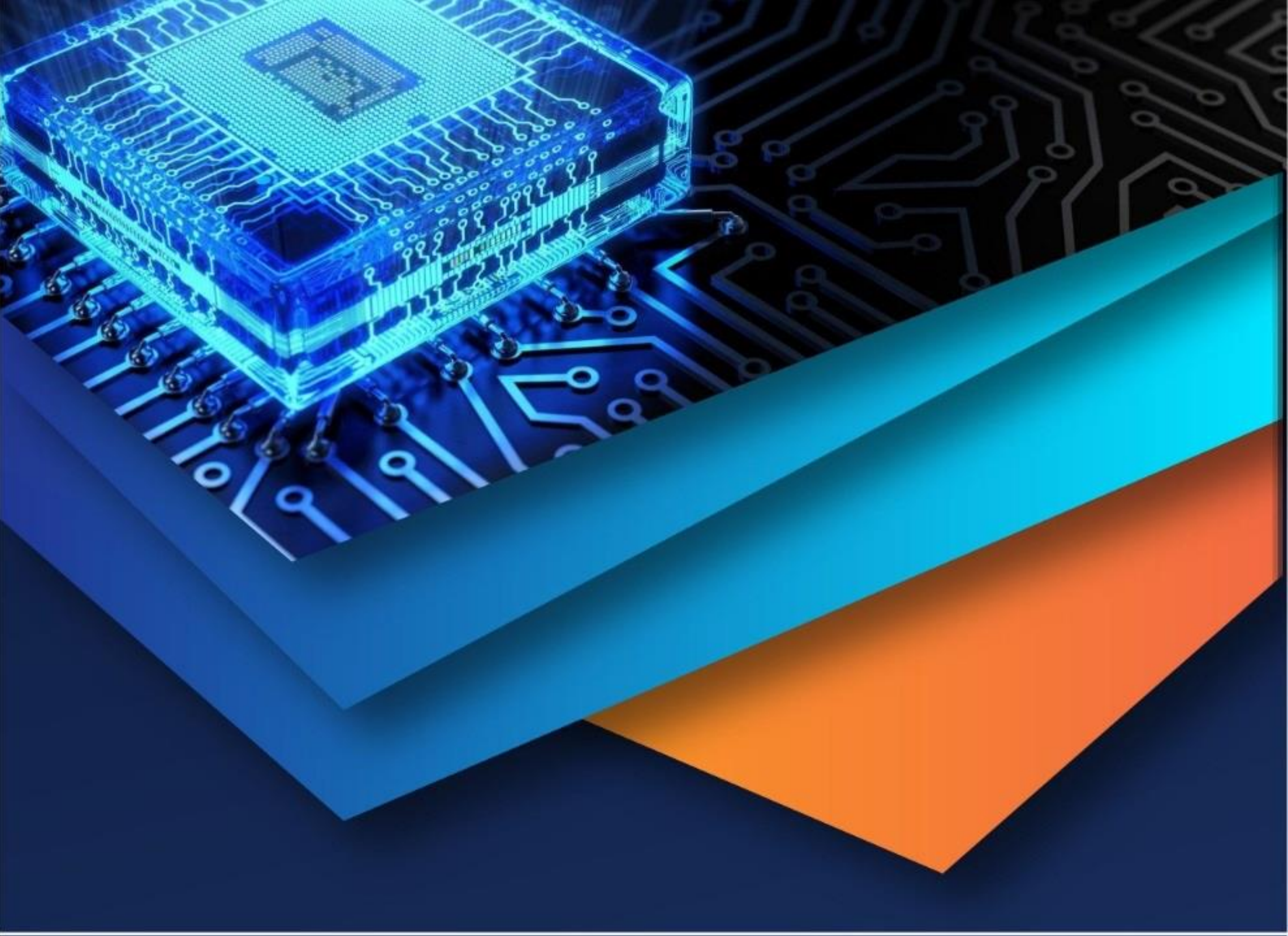

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