A Critical Review of Liquid Limit – Plasticity Index Relationships

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Abstract— Casegrande’s plasticity chart represents the plot between the values of liquid limit and plasticity index. Since the plastic limit determination is a difficult task in Atterberg limits determination in geotechnical practice, the plasticity chart is beneficial to predict the plastic limit from liquid limit. Several attempts are reported in literature wherein plasticity index has been linked with liquid limit. The plasticity index and liquid limit are fundamentally independent parameters and a linear relation exists between these two but the equations vary with the type of soil. Investigations in this direction conclusively proved that these exist definite linear relation between liquid limit and plasticity index but it is not linear.

Keywords— A line, Liquid limit, Plasticity chart, Plasticity Index, Plastic limit.

I. INTRODUCTION

Atterberg Limits and index properties have been in wide use for preliminary soil classification. Casegrande (1932) introduced the relation between liquid limit and plasticity index and designated as A-Line which has the equation \( I_p=0.73(w_L-20) \). Seed et al. (1964) presented an exhaustive work dealing with the fundamental aspects of the empirically defined values. Sridharan and Rao (1975) have discussed in detail the mechanisms controlling the liquid limit of clays.

Several attempts have been made to link liquid limit with plasticity index through empirical relations. The linear relationship between liquid limit and plasticity index suggested by Skempton and Norothy(1953) is of the form \( I_p=0.689(w_L-6.05) \). It has a correlation coefficient of 0.98. Based on the studies on Seed et al. (1964), kaolinite-bentonite-sand mixtures and illite-bentonite-sand mixtures, reported a different linear relationship between plasticity index and liquid limit and takes the linear form \( I_p=0.94(w_L-20.61) \) with a correlation coefficient of 0.997.

Another relationship between these two parameters introduced by Nagaraj and Jayadeva (1981) is of the form \( I_p=0.74(w_L-8) \) once again, confirm that Casegrande “A line” \( I_p=0.73(w_L-20) \) is valid only up to certain ranges of liquid limit values.

In this paper, an attempt is made to critically evaluate the validity of the A line based on the experimental investigations carried out on Cochin marine clays and by making use of the data pertaining to clays from different parts of the world.

II. EXPERIMENTAL INVESTIGATION

The engineering properties of marine clays of Cochin including their physical properties have been studied in detail by Jose et al. (1987, 1988, 1999). In an attempt to obtain the geotechnical properties of these marine sediments and to explore the possibility of obtaining a definite relationship between the liquid limit and plasticity index, innumerable tests were carried out for determination of index properties. Typical results from such index tests are given in table 1. It can be seen from the table that the liquid limit of these clays fall within a range of 96 to 137% and the plasticity index varies from 60 to 90%.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Description of soil</th>
<th>( w_L )</th>
<th>( w_p )</th>
<th>( I_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cochin Marin clay (Nettor)</td>
<td>137.5</td>
<td>47.5</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>Cochin Marin clay (Cheranello)</td>
<td>118.5</td>
<td>45.3</td>
<td>73.2</td>
</tr>
<tr>
<td>3</td>
<td>Cochin Marin clay (Kumbalam)</td>
<td>96</td>
<td>36.5</td>
<td>59.5</td>
</tr>
<tr>
<td>4</td>
<td>Cochin Marin clay (Munambam)</td>
<td>116.5</td>
<td>45.5</td>
<td>71</td>
</tr>
<tr>
<td>5</td>
<td>Cochin Marin clay (Parur 1)</td>
<td>108</td>
<td>42.8</td>
<td>65.2</td>
</tr>
<tr>
<td>6</td>
<td>Cochin Marin clay (Maradu)</td>
<td>137</td>
<td>55.2</td>
<td>81.8</td>
</tr>
<tr>
<td>7</td>
<td>Cochin Marin clay (Parur 2)</td>
<td>129</td>
<td>53.5</td>
<td>75.5</td>
</tr>
</tbody>
</table>

TABLE 1

PHYSICAL PROPERTIES OF COCHIN MARINE CLAY
III. RESULTS AND DISCUSSIONS

Fig 1 shows the plot between liquid limit and plasticity index for the Cochin marine clays from the different locations. All the points fall in a band which is very close to the Casagrande’s A-line. A statistical fit of the data yielded the equation,

\[ I_p = 0.63(w_L - 3.82) \]

With a correlation coefficient of 0.95

In order to verify the validity of the A-line for clays from different regions of the world, the authors collected data on index properties of clays from different parts and the resulting plots were compared with the Casegrande’s A-line

\[ I_p = 0.73(w_L - 20) \]

Fig 2 presents the liquid limit – plasticity index relationship for Kuttanad clays from Kerala, India, which yielded an equation

\[ I_p = 0.98(w_L - 39.5) \]

With a high correlation coefficient of 0.99

Similarly the data from clays of Japan (fig 3) yielded an equation

\[ I_p = 0.74(w_L - 18.24) \]

With a correlation coefficient of 0.96
Fig 4 Liquid limit – Plasticity index plot for Canadian clays

Fig 4 shows the plot between the liquid limit and plasticity index for the Canadian clays, yielding an equation

\[ I_p = 0.74(w_L - 14.86), \quad R = 0.97 \]

With a correlation coefficient of 0.97

Similarly the plot in the case of clays from Gulf of Mexico (fig 5) yielded an equation

\[ I_p = 0.84(w_L - 24.16) \]

With a high correlation coefficient of 0.99

Fig 5 Liquid limit – Plasticity index plot for Gulf of Mexico clays

Fig 6 Liquid limit – Plasticity index plot for Norwegian clays

Fig 6 presents the liquid limit – plasticity index relationship in the case of Norwegian clays which yielded an equation

\[ I_p = 0.79(w_L - 17.2), \quad R = 0.98 \]

With a correlation coefficient of 0.98

The relationship between the liquid limit and plasticity index for clays from the above regions put together (Fig 7) yielded a curvilinear equation

\[ I_p = 0.74w_L + 4.59w_L^2 \]

With a correlation coefficient of 0.99

Fig 7 Liquid limit – Plasticity index plot for different parts of the world
IV. CONCLUSIONS

Based on the experimental investigations on Cochin marine clays and the index properties data collected from different parts of the world, the following conclusions are made.

- The Casagrande’s A-line cannot be taken as a general relationship between the liquid limit and plasticity index for all soils.

- Clays from different regions yield different relationships between liquid limit and plasticity index. Data for some of the clays give plots very close to A-line (eg:: Japan clays and Cochin marine clays), but some other plots deviate very much from the Casagrande’s A-line (eg: Kuttanad clays, Norwegian clays).

- Liquid limit and plasticity index will not yield a straight line relationship, but takes a curvilinear form. Hence it is more appropriate to use equation \( I_p = 0.74 \times w_L + 4.59 \times w_L^2 \) to represent the relationship between liquid limit and plasticity index and there by a more realistic prediction of the plastic limit can be made

REFERENCES


