A Parametric Study of Estimating Index Properties and Compaction Characters of Kaolinite – Bentonite - Sand Mixtures

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Abstract

The study of compacted soil becomes more important in the present scenario, where the lack of good constructional site is forcing the people to go for using the site which have been considered since ages as unsuitable for constructional activities which necessitate reclaiming the marginal lands after subjecting these to various ground improvement techniques. It is observed that the compaction of coarse grained soil is purely a physical problem whereas the behavior of fine grained soil is expected to be physico- chemical in nature by virtue of clay mineralogy. The relative proportion of clay minerals present in fine grained soil can be represented by least active clay mineral like kaolinite to most active clay mineral montmorillonite. The different percentage of these clay minerals present in fine grained soil requires a detailed study by virtue of their physico-chemical phenomenon. In view of the above limitation, an attempt has been made in the present experimental study to correlate the index properties and compaction characteristics (at different energy levels) of artificially prepared soil samples by design mix proportions of commercially available kaolinite, bentonite and sand in different proportions.. The results obtained in present experimental study agree well with the results of natural fine grained soils across the globe as reported in the literature. The results obtained serves as a guideline in preliminary design of earthen embankment pavement, airfields, etc.,

Keywords: Clay minerals, Compaction, Design Mix Proportion, Marginal Lands.

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1. INTRODUCTION

1.1 GENERAL:

Soils occurring in nature are composed of both coarse and fine-grained soils. Coarse-grained soil possesses a physical phenomenon. Whereas, fine-grained soil possess a physico-chemical phenomenon because of the presence of clay minerals. Physical properties and chemical properties of soil also depend on the clay mineralogical composition. The fine-grained soils are having smaller size particles and are having more surface area leading to more water holding capacity, in relative comparison to coarse-grained soils.

Due to the mechanism which is predominantly controlling the behavior of kaolinite and montmorillonitic soils, the field of study of fine-grained soils attracted many researchers. It is important to note here that, kaolinitic and montmorillonitic soils exhibits opposite trends of behavior. It is observed from the existing documented geotechnical literature that, most of the studies related to fine-grained soils are region specific. Hence it can be observed that, a generic solutions related to the behavioral study of fine-grained soils proves to be very costly and time consuming. Any parametric study related to the behavior of fine-grained soils based on design mix proportions representing these soils in the laboratory is a value addition to the existing literature.

2. LITERATURE REVIEW

- **Daksinamurthy and Raman (1973)** proposed a simple method of identifying an expansive soil. An attempt have been made on identifying the expansive soils from liquid limit, plastic index and shrinkage index values
- **Sivapullaiah** and **Sridharan (1985)** they made a detailed investigation on liquid limit on soil mixtures including bentonite, kaolinite, sand and silts.
- **Sudhendu Saha and Chattopadyay (1988)** made a detailed study on prediction of compaction characteristics of soils from index properties. An attempt has been made on the development of correlation between plastic properties of inorganic fine grained soils of alluvial nature and reduced Proctor dry density at various moisture content in terms of liquid limit and plasticity index to liquid limit ratios
- **Brian Wagg (1990)** conducted experimental study on index properties of clay mixtures. A void ratio model is proposed which shows that the structure of clay-silt mixture is dominated by the clay fraction porosity around 30% clay compositions.
- **Bansal and Ghuman (1997)** made a investigation based on experimental study, correlations developed between compaction and plasticity characteristics, Atterberg limits and percentage of fines.
- **Vipulanandan, Elesvwarapu (2008)** made a detailed study on index properties and compaction characteristics of kerosene contaminated clayey soil. Effect of organic matter and kerosene content on the index properties and compaction characteristics (Harvard miniature) of the clay soils was quantified.
- **YUERU CHEN (2011)** made a detailed study on undrained strength characteristics of compacted bentonite/sand mixtures. Results from this study illus-

trate the effects of clay/sand mix proportion, compaction moisture content, compaction energy, and confining pressure on the shear strength and stress-strain behavior of compacted bentonite/sand mixtures.

- **Ash-Shu'ara et al (2018)** made an attempt to study the effects of addition of coarse sand particles on engineering properties of clay soil. The experimental results show that the optimum moisture content decreases with increase in addition of sand content while maximum dry density and CBR values increases with increase in sand content.

3. METHODOLOGY

Materials used for the present experimental study are commercially available china clay (kaolinite) and bentonite (montmorillonite) which were procured from Bengaluru, Karnataka and stored in air tight plastic container to keep it in dry condition.

Sand was procured from river Cauvery near T Narasipura, Karnataka. It was wet washed through 75microns sieve to remove the organic content and subsequently dried in an oven for 24 hours at 110°C. Then the sand was sieved through 425microns sieve to obtain fine sand fraction and the sieved sand was stored in air tight plastic containers.

Bentonite, china clay and river sand were mixed in different mix proportions (1-8) to replicate the natural fine-grained soils. The mix proportions were prepared by keeping bentonite percent as constant and varying china clay content (i.e, varying from 10% to 80%). Index properties tests and compaction tests were conducted in the laboratory as per BIS specifications.

4. RESULTS AND DISCUSSIONS

Table 1 shows mix proportions prepared for the experimental work

Table 1.

Mix proportion	Combinations (%)
1	10K+10B+80S
	20K+10B+70S
	30K+10B+60S
	40K+10B+50S
	50K+10B+40S
	60K+10B+30S
	70K+10B+20S
	80K+10B+10S
2	10K+20B+70S
	20K+20B+60S
	30K+20B+50S
	40K+20B+40S
	50K+20B+30S
	60K+20B+20S
	70K+20B+10S
3	10K+30B+60S
	20K+30B+50S
	30K+30B+40S
	40K+30B+30S
	50K+30B+20S
	60K+30B+10S
4	10K+40B+50S
	20K+40B+40S
	30K+40B+30S
	40K+40B+20S
	50K+40B+10S
5	10K+50B+40S
	20K+50B+30S
	30K+50B+20S
	40K+50B+10S
6	10K+60B+30S
	20K+60B+20S
	30K+60B+10S
7	10K+70B+20S
	20K+70B+10S
8	10K+80B+10S

Figure 1 shows the grain size distribution of the mix proportion.

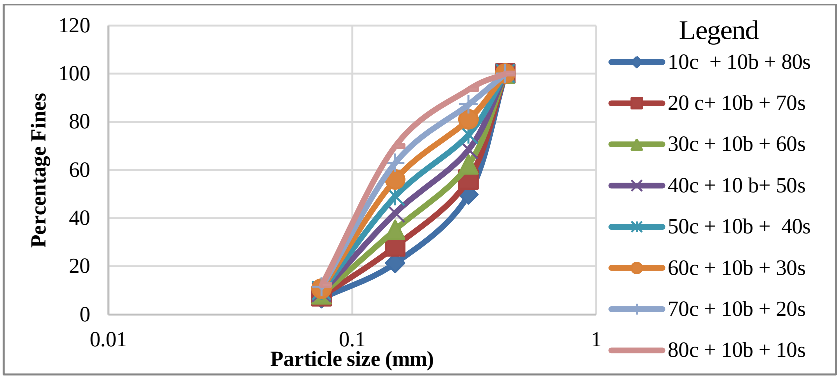

Fig 1: Grain size distribution of mix proportions

The grain size distribution of bentonite, china clay and river sand done alone by grain size analysis and the grain size distribution of mix proportions were done by linear law of mixtures.

Table 2 shows the co-efficient of uniformity and co-efficient of curvature of china clay, bentonite and sand.

Table 2.

	China Clay	Bentonite	Sand
Co-efficient of uniformity(Cu)	2.79	2.86	1.5
Co-efficient of curvature (Cc)	1.72	1.78	1.38

Figure 2 shows Variation of Atterberg limits of mix proportion with percent china clay.

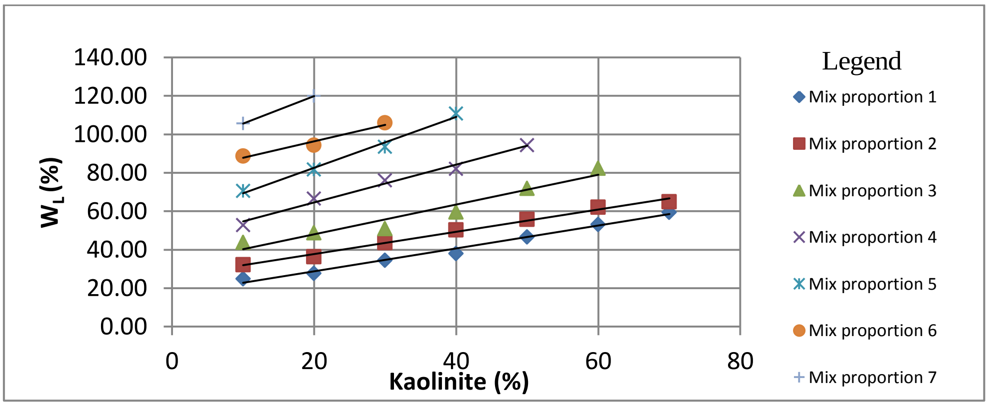

Fig.2. Variation of liquid limit v/s percent kaolinite

Figure 3 shows the variation of plastic limit with percent china clay.

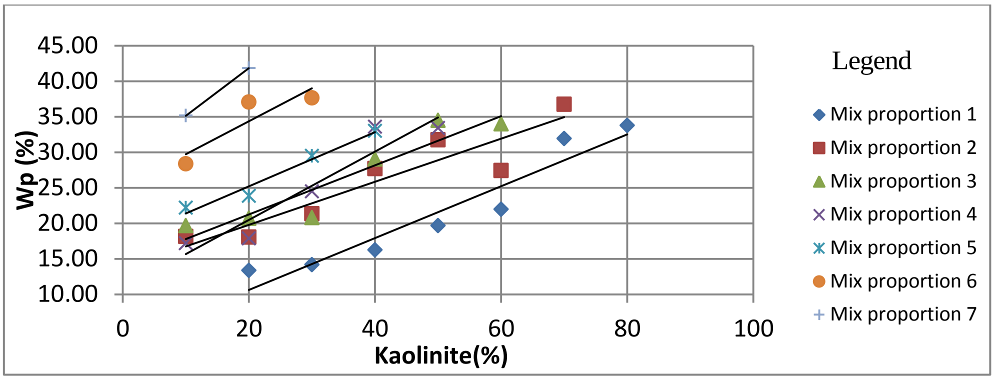

Fig.3. Variation of plastic limit v/s percent china clay

From figures 2 & 3, it is observed that the value of liquid limit & plastic limit increases with increase in percentage of china clay due to increase of water holding capacity of mix proportions which can be compared with natural fine grained soil behavior .

Figure 4 shows the variation of shrinkage limit with percent china clay in mix proportion.

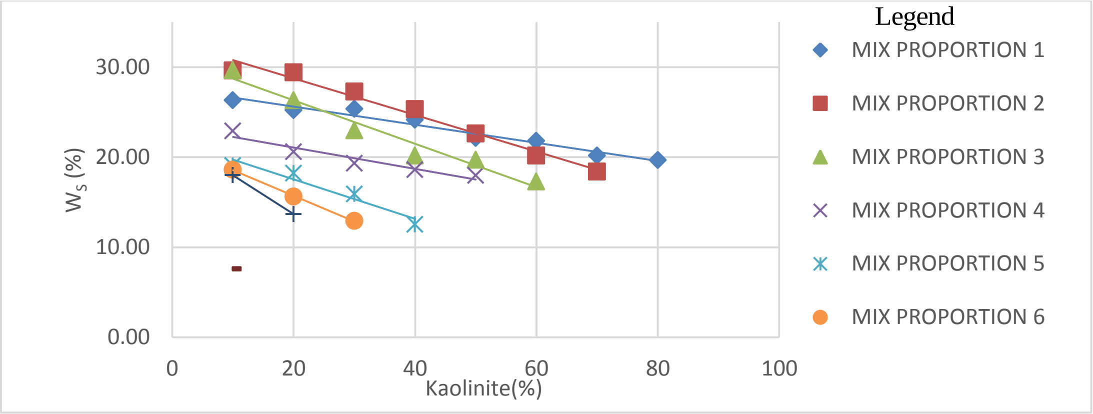

Fig.4. Variation of shrinkage limit v/s percent china clay

From fig 4, it is observed that, the value of shrinkage limit decreases with increase in percentage of china clay due to packing phenomenon of fines present in mix proportions. This tendency highlights that, shrinkage limit can be regarded to be reorientation of fines present in fine-grained soils rather than plasticity character of the soil.

The shrinkage limit of the soil is primarily controlled by the relative grain size distribution of the soil.

Figure 5 shows the new plasticity chart developed for mix proportions.

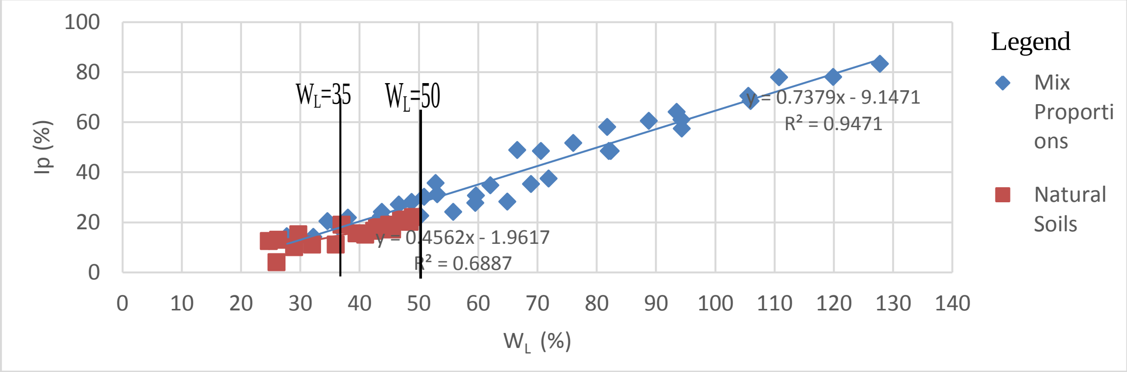

Fig.5. variation of plasticity index v/s liquid limit of mix proportions

The equation of the trend line can be deduced as **I_p=0.7379 (W_L - 12.39)** which is akin to equation of A-line i.e., **I_p=0.73 (W_L - 20)** proposed by **Arthur Casagrande**. The liquid limit of the mix proportions varying from **25% - 130%** which represents the liquid limit values as in the original plasticity chart i.e., from **20%-100%**. Similar to the original plasticity chart a vertical can be drawn at W_L at **35%** and **50%** which can be used for classification of purpose.

Figure 6 shows variation of optimum moisture content with liquid limit of soil mixtures at various energy levels

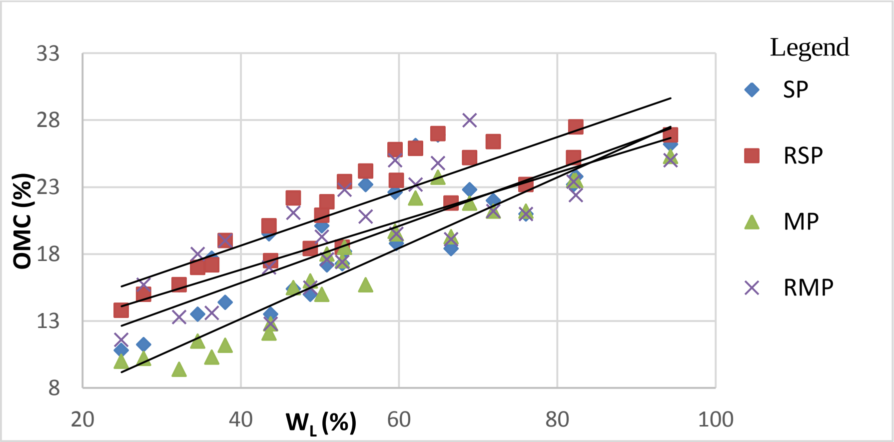

Fig.6. variation of OMC with liquid limit of mix proportion for different energy level

From fig 6, it is observed that the optimum moisture content increases with increase in liquid limit which is similar to natural fine grained soil behavior. OMC for different compaction energy levels can be estimated reasonably with a fair degree of accuracy.

Table 3 presents the correlation of OMC with liquid limit of mix proportion for various energy levels with their correlation coefficient.

Table 3.

ENERGY LEVELS	EQUATIONS	R
Standard Proctor	OMC= $0.2125W_L+7.346$	0.83
Reduced Standard Proctor	OMC= $0.2025W_L+10.539$	0.88
Modified Proctor	OMC= $0.264W_L+2.5977$	0.94
Reduced Modified Proctor	OMC=$0.1813W_L+9.5818$	0.76

Figure 7 shows variation of optimum moisture content with plastic limit of mix proportions for various energy levels.

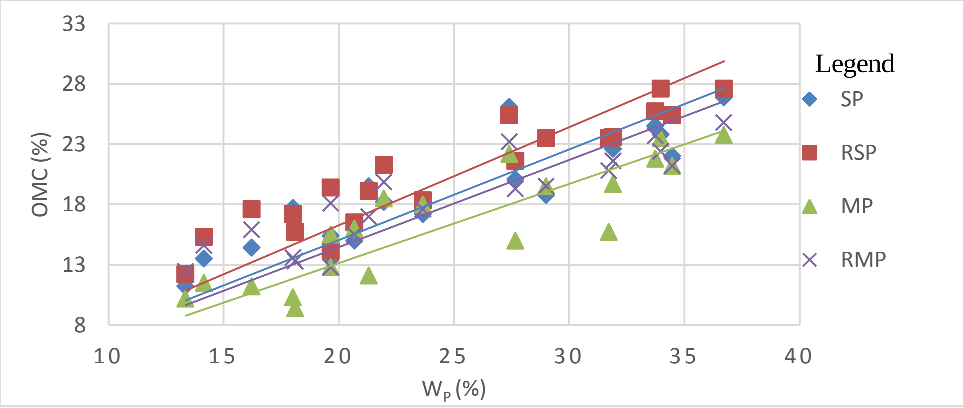

Fig.7. variation of OMC with plastic limit of mix proportions for different energy levels

From figures 6 & 7 it can be observed that the optimum moisture content increases with increase in liquid limit & plastic limit due to increase in water holding capacity of soil mixtures which is akin to relationship between OMC , W_L & W_P of natural fine grained soils as reported in the documented literature .

Table 4 present the correlation of OMC obtained from different compactive energy with plastic limit along with correlation coefficient.

Table 4.

ENERGY LEVELS	EQUATIONS	R
Standard Proctor	OMC = 0.7524WP	0.84
Reduced Standard Proctor	OMC = 0.8134WP	0.85
Modified Proctor	OMC = 0.6564WP	0.86
Reduced Modified Proctor	OMC = 0.7231WP	0.75

Table5 shows the comparison of equations obtained from literature with experimental results obtained for different energy levels

Table 5.

Energy Levels	Literature	Experimental
Standard proctor	$OMC_{(SP)} = 0.92\ W_P$	$OMC_{(SP)} = 0.75\ W_P$
Reduced Standard proctor	$OMC_{(RSP)} = 1.0\ W_P$	$OMC_{(RSP)} = 0.81\ W_P$
Modified proctor	$OMC_{(MP)} = 0.7\ W_P$	$OMC_{(MP)} = 0.66\ W_P$
Reduced Modified proctor	$OMC_{(RMP)} = 0.7\ W_P$	$OMC_{(RMP)} = 0.72\ W_P$

Figure 8 shows variation of maximum dry density with optimum moisture content for mix proportions for different energy levels

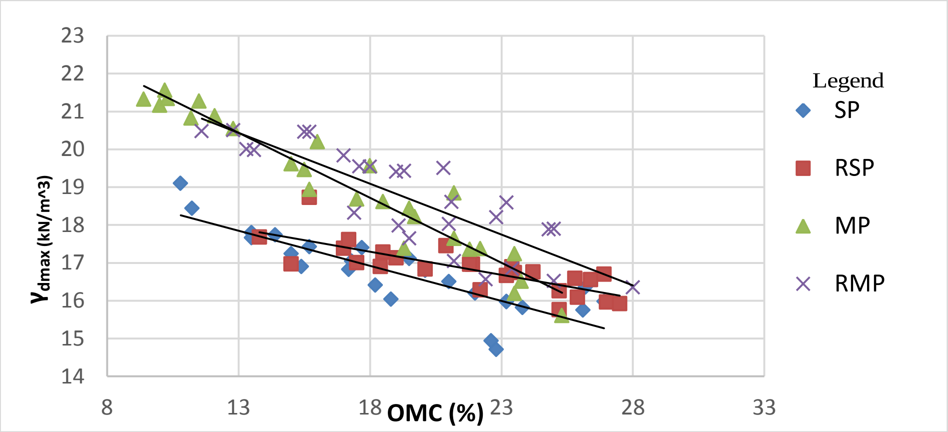

Fig.8. variation of γ_{dmax} with OMC for different energy levels

From fig 8, it can be observed that the value of maximum dry density decreases with increase in optimum moisture content irrespective of compaction energy levels.

Table 6 shows the correlation of maximum dry density with OMC of mix proportion for different energy levels with correlation coefficient.

Table 6.

ENERGY LEVELS	EQUATIONS	R^2	R
Standard Proctor	γdmax = -0.1851OMC + 20.255	0.72	0.85
Reduced Standard Proctor	γdmax = -0.1222OMC + 19.494	0.62	0.79
Modified Proctor	γdmax = -0.3434OMC + 24.901	0.93	0.96
Reduced Modified Proctor	γdmax = -0.2682OMC + 23.918	0.71	0.84

Dry density at plastic limit of mix proportion can be determined by substituting the value of plastic limit as the water content in the following equation.

$$\boldsymbol{\gamma}_{\mathbf{d}} = \frac{G\,\boldsymbol{\gamma}\mathbf{d}}{(1+WG)} \text{ -------- } (1)$$

Figure 9 shows the variation of maximum dry density with maximum dry density at plastic limit for mix proportions at different energy levels

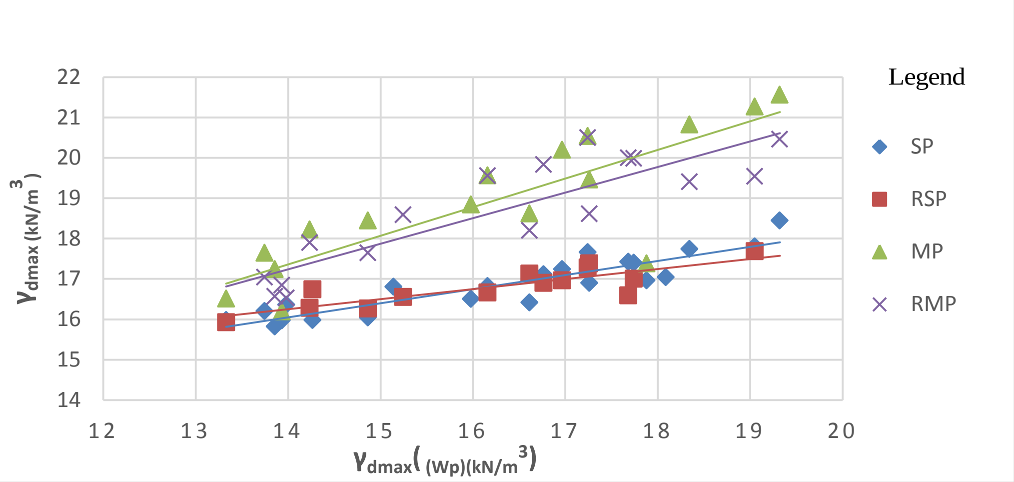

Fig.9. variation of γ_{dmax} with $\gamma_{dmax\,(Wp)}$ at different energy levels

From fig 9, it can be observed that the maximum dry density increases with increase in maximum dry density at plastic limit.

Table 7 shows the correlation of maximum dry density with maximum dry density at plastic limit of mix proportion for different energy levels with correlation coefficient.

Table 7.

ENERGY LEVELS	EQUATIONS	R^2	R
Standard Proctor	γdmax = 0.3487 γdmax(Wp) + 11.168	0.82	0.91
Reduced Standard Proctor	γdmax = 0.2482 γdmax(Wp) + 12.778	0.71	0.84
Modified Proctor	γdmax = 0.7095 γdmax(Wp) + 7.4297	0.70	0.84
Reduced Modified Proctor	γdmax = 0.6351 γdmax(Wp) + 8..3443	0.77	0.88

5. CONCLUSIONS

- The percent fines of the mix proportions can be correlated with liquid limit, plastic limit and shrinkage limit.
- The relationship between maximum dry density and optimum moisture content values for different energy levels have a very good correlation which can be compared with the results from documented literature.
- The compaction characteristics like maximum dry density and optimum moisture content can be correlated with liquid limit and plastic limit.
- The liquid limits of artificially prepared mix proportions are representing the liquid limits of natural soils in the proposed plasticity chart.
- The plasticity chart developed is well correlated with the existing plasticity chart developed by Arthur Casagrande i.e., the equation of trend line proposed in plasticity chart, $I_P = 0.7379\ (W_L-12.39)$ is akin to equation of A-line of plasticity chart of natural soils i.e., $I_P = 0.73\ (W_L-20)$.

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