Casagrande Liquid Limit Testing Of Jamshoro Soil By One Point Method

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Abstract-The Liquid limit (LL) tests are considered essential to determine the index properties of soil. Casagrande liquid limit test is one of these tests and universally recognized for soil testing. The purpose of this research work is to introduce the constant values of index (e) and Number of Blows for A-7-6 (AASHTO Classification) clayey shale type soils using one point formula. 100 samples of A-7-6 soil were collected from Jamshoro (Pakistan) zone and multi point Casagrande liquid limit laboratory tests were performed. After obtaining test results, samples were squeezed out with appropriate range of LL covering maximum number of samples. Suitable range of number of blows was chosen and the most appropriate index (e) value for selected soil samples was calculated. The experimental results were compared with one point formula results. The reliability of LL between experimental results and one point formula results exhibited excellent relationship.

Keywords-Jamshoro, Liquid Limits, Casagrande, Clayey Soil, One Point Formula, Index Value.

I. INTRODUCTION

The liquid limit (LL) and plastic limit (PL) of soil, also called consistency limits or Atterberg limits, are very important physical parameters for soil science [i-iii]. Atterberg observed that soil is less resistant against moulding at specified quantity of water. Furthermore, the cracks may be developed in the soil at lower moisture content [iv]. In order to distinguish the states of soil or clay, Atterberg introduced that at lowest water content, (expressed in mass percent of the clay dried at 120 °C) the body can be rolled into threads without failure and this state is called the plastic limit of soil. The liquid limit is defined as a state in which the body takes the shape of fluid after processing through a specified equipment [iv-v]. Later, Reed [vi] used the term "consistency" referring to the states of ceramic raw materials relying on water content. According to Reed [vi], the quantity of water required to change normal clay into plastic state is referred to as plastic limit. The initial effect of adding water to dry clay is the increase in cohesion of molecules which gradually reaches to the removal of air from voids between particles. Adding more water into the voids tends the body to easily fail under deformation. Slurry system is established at high water contents body starts to flow. That phase is referred to as liquid limit of that body. The difference in the quantity of water at two limiting points, related to the dry mass of the clay, is expressed as the "plasticity index" (PI), [vi]. The liquid and plastic limits define the transitions between liquid and plastic behavior. These limits can give significant information about the behavior of soil [vii].

In order to determine plastic and liquid limits of soil, Casagrande investigated various soil types using an innovative method to determine the plasticity of clayish and non-clayish materials [viii]. Casagrande method is widely used to evaluate Atterberg's limits. However, it utilizes large number of variables which results in a complex comprehensive relationship between the parameters and performance of soil. This problem was solved by a probabilistic approach put forwarded by Gutiérrez (2006). He used regression analysis and expressed linear behavior of consistency limits for soil [ix].

The most commonly used methods to evaluate the liquid limit of soil are multipoint test and one-point tests methods [x]. Multipoint test method is recommended to obtain highly précised results. Multipoint tests are performed for organic soils or the soils existing in marine environment. The one-point liquid limit test is based on the experience that the slope of the liquid limit flow line for soils within a given geologic environment is essentially a constant on a logarithmic plot. Thus, the liquid limit can be determined provided that the constant defining the slope has been established from correlations on the soil in question. The one-point liquid limit test is preferred in areas where the soils are geologically similar. Moreover, adequate correlations defining the slope of the liquid limit flow line are required to be made and consistency required to cause closure at 20-30 blows. One-point method demands vigilant observation of duration taken by the specimen to achieve its liquid limit. Therefore, inexperienced technicians generally avoid one-point testing. One-point method does not require high cost, however, the lack of accuracy is a limitation of this method which limits its use in controlling materials [xi].

Established to designate fine grained soils as clay and silt, universally accepted standard test methods have been solely performed on soils sieved through # 40 mesh. Because consistency limits are characteristic to fine-grained soils, and the material passing through # 40 mesh may include a significant amount of sand, the use of a # 40 sieve for this purpose may lead to significant errors regarding the class or plasticity level of a soil. The Atterberg limits are the basic parameters for classifying the plastic soils. Two main approaches are available in the literature to find the liquid limit values: the percussion method (originally proposed by Casagrande) [xii], and the fall cone method (originally suggested by Geotechnical Commission of Swedish State Railways (GCSSR) [xiii]). Based on the fundamentals of the above mentioned two methods, several methods were developed and implemented worldwide. The Bureau de normalization du Quebec, and then, the Canadian Standards Association, defined their own standards concerning these tests according to the devices and procedures described by Swedish Commission and Casagrande, for fall cones and percussion methods, respectively [viii-xiv]. They also proposed simple and new Single Point Method for determining the Liquid limit values by using Casagrande and fall cone methods. Canadian scientists prefer the fall cone method due to its advantages defined by Garneau and Le Bihan [xv]. Sanzeni et al. [xvi] examined the specific surface and hydraulic conductivity of fine-grained soils. They applied several testing methods and the one point method showed better performance. Kumar and Kumar [xvii] used various industrial wastes and examined the stabilization of clayey type soil. The results showed that fly ash has a significant impact on the liquid limit of soil.

In general, the purpose of this research work is to introduce the constant values of index (e) and Number of Blows for A-7-6 clayey shale type soils used in One Point Formula of Liquid limit by Casagrande method. Such soil exists in the Jamshoro (Pakistan) zone. The soil samples have been taken from different parts of Jamshoro. This research will minimize the efforts and will provide easiness and time saving for the researchers and designers in Jamshoro zone to calculate the liquid limit of soil existing in that area. The liquid limit values calculated in this research can be used directly without performing several liquid limit laboratory tests every time. A comparison of the experimental and one point formula results is presented to ensure the authenticity of findings.

II. Methodology

A. Liquid Limit Apparatus

The Casagrande liquid limit instrument, as shown in Fig. 1, suggested by Indian standards [xviii- xix], was selected for performing the laboratory tests on the specimens. The drop height adjustment of the cup was 10 mm. The crank was turned at 2 revolutions per second while holding the guage in position against the tape and cup in order to check the adjustment. The grooving tool with a tip width and depth of 2.5 mm and 8.0 mm, respectively, was used. The soil samples were sieved through a 20.3 cm diameter (No. 40) sieve, in accordance with the requirements of ASTM Specification [viii] with a rim of 5 cm above the mesh. Balance of capacity was 500 grams and sensitivity was 0.01gram. Thermostatically controlled oven with a capacity up to 250 0C was used for drying the soil samples at controlled temperature. Porcelain evaporating dish of 12-15 cm diameter was used and the spatula used for mixing was flexible with 8 cm long and 2 cm wide blade. Palette knives of 20 cm long and 3 cm wide blade were utilized to properly mix and fill the testing cup. Containers were kept air-tight and non-corrodible for determination of moisture content.

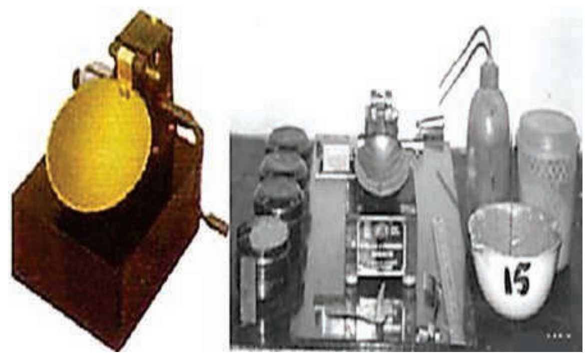

Fig. 1. Casagrande apparatus

B. Mixture details

The ground was excavated up to 3 ft with the help of available instruments and labor and 100 samples of clayey soil were collected. The samples were placed in the oven for 24 hours. The dried samples were then sieved using # 40 meshes to achieve a 300 gram sample. It was observed that the sample has no material retained on the 425-urn (No. 40) sieve. A mixture was prepared by adding distilled water to the samples on the glass plate using the spatula. Initial mixing time was 30 minutes. The prepared mixture was placed in open air to achieve the desired moisture content. Water content of the soil was brought to a consistency by 15 to 25 blows of the liquid limit device to close the groove. The soil was re-mixed 24 hours before the tests and LL was determined.

I. Results

After the collection of all the samples, the liquid limit test was performed. The experimental procedure was repeated for all the 100 samples and 100 graphs were plotted following the procedure suggested by [xx]. The flow curve of one sample as a typical curve is shown in Fig. 2. The typical curve was plotted by considering number of blows and the water content of the sample. After the sample was cut and groove was made, the crank device was rotated at 2 revolutions per second. The number of blows (N) were counted that caused the sample closure (make the paste so that N begins with a value higher than 35). When N was in the range of 15 to 40, the sample was collected and weighed. When soil was not dried as per requirement, the mixture was exposed to fan and continuous mixing was performed, rather than adding more soil. Then, the cup was cleaned after each trial. A minimum of three trials with values of N ~ 15 to 40 were performed and after 24 hours, the corresponding water content (%) was determined. The resultant flow curve was plotted as shown in Fig. 2. However, as per suggested by codes, the liquid limit values of all the samples were selected at 25 number of blows. Meanwhile, the liquid limit values of all the samples with their respective number of blows are shown in Table I.

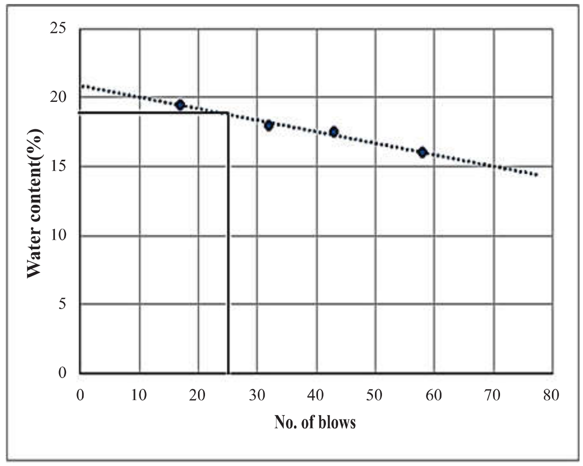

Fig. 2. Typical flow curve of the liquid limit for one sample

TABLE I
LIQUID LIMIT VALUES AND NUMBER OF BLOWS OF ALL THE SAMPLES

Sample No.	Number of Blows	Liquid Limit (%)	Sample No.	Number of Blows	Liquid Limit (%)
01	25	18	51	25	43
02	25	42	52	25	19
03	25	44	53	25	45
04	25	16	54	25	52
05	25	26	55	25	23
06	25	28	56	25	50
07	25	21	57	25	52
08	25	33	58	25	22
09	25	21	59	25	52
10	25	21	60	25	28
11	25	40	61	25	16
12	25	57	62	25	24
13	25	36	63	25	16
14	25	21	64	25	28
15	25	52	65	25	18
16	25	29	66	25	22
17	25	25	67	25	19
18	25	18	68	25	18
19	25	19	69	25	18
20	25	29	70	25	19
21	25	17	71	25	18
22	25	22	72	25	19
23	25	26	73	25	20
24	25	44	74	25	18
25	25	18	75	25	18
26	25	18	76	25	20
27	25	52	77	25	43
28	25	24	78	25	42
29	25	19	79	25	26
30	25	53	80	25	28

31	25	46	81	25	51
32	25	17	82	25	58
33	25	19	83	25	52
34	25	46	84	25	33
35	25	26	85	25	87
36	25	19	86	25	40
37	25	18	87	25	20
38	25	19	88	25	36
39	25	22	89	25	42
40	25	56	90	25	38
41	25	22	91	25	20
42	25	16	92	25	18
43	25	16	93	25	30
44	25	22	94	25	55
45	25	17	95	25	20
46	25	16	96	25	16
47	25	18	97	25	19
48	25	20	98	25	30
49	25	18	99	25	52
50	25	28	100	25	42

As can be seen in Table I, the results indicate variations in the readings for the liquid limits. In order to precise the results, the samples are divided into different groups according to the similarity exists in the values of liquid limits. Fig. 3 shows 56 samples out of 100, which contains the liquid limit range from 16 to 26. The major reason to select this range of the liquid limit was obtained from the literature. As it was observed that most of researchers have reported that the liquid limit range of Jamshoro soil is 15-25 [xxi-xxiv]. Therefore, authors believe that the 16-26 is the most suitable range to compute and investigate the various parameters of the liquid limit for the Jamshoro region. The detailed liquid limit values of the selected 56 samples are presented in Table II.

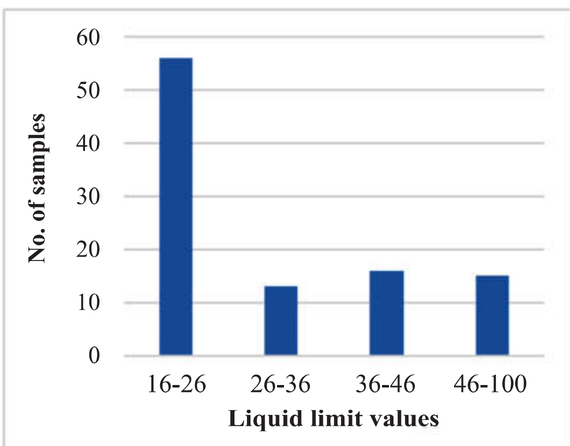

Fig. 3. Number of samples in Different LL ranges

TABLE II
LIQUID LIMIT VALUES OF SELECTED 56 SAMPLES

No.	Liquid Limit Values	No: Of Samples
1	16	6
2	17	3
3	18	14
4	19	9
5	20	6
6	21	4
7	22	6
8	23	1
9	24	2
10	25	1
11	26	4

III. COMPUTATION OF INDEX (e) VALUES

A range of number of blows between 20 and 30 was selected as suggested in [xvi]. From this range, the values of 20, 26 and 30 number of blows were further selected to calculate the index (e) values. The water content values were 19%, 16% and 16%, respectively, which were computed from the liquid limit graphs as shown in Fig. 4. The water content values for the rest of the samples were also drawn from the previously prepared liquid limit graphs in a similar manner.

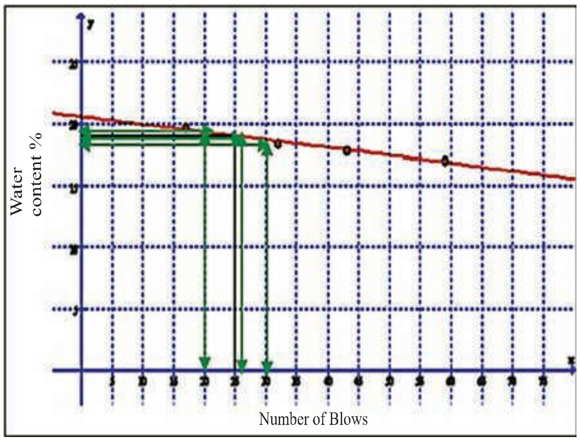

Fig. 4. Water content values @ different number of blows

A. Index (e) values @ 20-26-30 blows

Eq. 1 (One Point formula of liquid limit) is used to find the index (e) values.

$$LL = W*(N/25)^{e} \quad (1)$$

Now by rearranging this formula,

$$e = \log(LL/w) \quad \log(N/25) \quad (2)$$

Where;

LL= Liquid Limit Values, W= Water Content (%), N= Number of Blows and e = Index (slope of the flow line).

At 20, 26 and 30 number of blows, the calculated index (e) values of the selected samples having Liquid Limits 16, 17, 18, 19, 20, 21, 22, 24 and 26 are given in Tables III-X, respectively. The comparison of obtained index values of all 56 specimens in the range 16-26 is presented in Fig. 5.

TABLE III
INDEX (e) VALUES OF LL=16 AT 20, 26 & 30 NUMBER OF BLOWS

S. No.	LL	W @ 20 Blows	W @ 26 Blows	W @ 30 Blows	Index (e) @ 20 Blows	Index (e) @ 26 Blows	Index (e) @ 30 Blows
1.	16	19	15.8	14	0.770	0.320	0.732
2.	16	17.5	15.6	15.8	0.401	0.646	0.068
3.	16	16.5	15.75	15.5	0.138	0.402	0.174
4.	16	17	15.67	15.2	0.271	0.531	0.281
5.	16	16.5	15.9	15.58	0.138	0.159	0.146
6.	16	16.5	15.85	15.5	0.138	0.240	0.174

TABLE IV
INDEX (e) VALUES OF LL=17 AT 20, 26 & 30 NUMBER OF BLOWS

S. No.	LL	W @ 20 Blows	W @ 26 Blows	W @ 30 Blows	Index (e) @ 20 Blows	Index (e) @ 26 Blows	Index (e) @ 30 Blows
1.	17	18	16.6	16.15	0.2561	0.607	0.2813
2.	17	18.5	16.7	16.5	0.3789	0.453	0.1637
3.	17	17.3	16.8	16	0.0783	0.301	0.3325

TABLE V
INDEX (e) VALUES OF LL=18 AT 20, 26 & 30 NUMBER OF BLOWS

S. No.	LL	W @ 20 Blows	W @ 26 Blows	W @ 30 Blows	Index (e) @ 20 Blows	Index (e) @ 26 Blows	Index (e) @ 30 Blows
1.	18	19	17.75	17.75	0.2422	0.3566	0.0767
2.	18	19.1	17.8	17	0.2658	0.2848	0.3135
3.	18	19.2	17.85	16.5	0.2892	0.2133	0.4772
4.	18	19.3	17.88	16	0.3125	0.1705	0.6460
5.	18	18.4	17.9	16.2	0.0984	0.1420	0.5778
6.	18	18.5	18	17.5	0.1227	0	0.1545
7.	18	19.5	17.98	17.58	0.3587	0.0283	0.1294
8.	18	18.08	17.88	17.65	0.0198	0.1705	0.1077
9.	18	19	17.78	17.4	0.2422	0.3135	0.1859
10.	18	19.1	17.82	17	0.2658	0.2562	0.3135
11.	18	19.5	17.92	16.5	0.3587	0.1136	0.4772
12.	18	19	17.88	17.2	0.2422	0.1705	0.2493
13.	18	19.8	17.9	17.9	0.4271	0.1420	0.0305
14.	18	18.1	17.68	17.52	0.0248	0.4573	0.1482

TABLE VI
INDEX (e) VALUES OF LL=19 AT 20, 26 & 30 NUMBER OF BLOWS

S. No.	LL	W @ 20 Blows	W @ 26 Blows	W @ 30 Blows	Index (e) @ 20 Blows	Index (e) @ 26 Blows	Index (e) @ 30 Blows
1.	19	20.1	18.5	17	0.2522	0.6799	0.6100
2.	19	20	18.7	18	0.2298	0.4058	0.2965
3.	19	19.4	18.6	17.5	0.0933	0.5425	0.4510
4.	19	20.2	18.65	18.5	0.2744	0.4740	0.1462
5.	19	19.7	18.85	18.58	0.1621	0.2020	0.1226
6.	19	19.9	18.88	18	0.2074	0.1615	0.2965
7.	19	19.1	18.87	18.7	0.0235	0.1750	0.0872
8.	19	19.5	18.9	18.7	0.1164	0.1345	0.0872
9.	19	19.85	18.92	18.1	0.1961	0.1075	0.2661

TABLE VII
INDEX (e) VALUES OF LL=20 AT 20, 26 & 30 NUMBER OF BLOWS

S. No.	LL	W @ 20 Blows	W @ 26 Blows	W @ 30 Blows	Index (e) @ 20 Blows	Index (e) @ 26 Blows	Index (e) @ 30 Blows
1.	20	20.2	19.5	19	0.045	0.646	0.281
2.	20	21	19.6	18	0.218	0.515	0.578
3.	20	22	19.6	18.2	0.427	0.450	0.517
4.	20	20.3	19.7	18.5	0.067	0.385	0.427
5.	20	20.5	19.8	19	0.110	0.256	0.281
6.	20	20.8	19.9	19.5	0.175	0.128	0.138

TABLE VIII

INDEX (e) VALUES OF LL=21 AT 20, 26 & 30 NUMBER OF BLOWS

S. No.	LL	W @ 20 Blows	W @ 26 Blows	W @ 30 Blows	Index (e) @ 20 Blows	Index (e) @ 26 Blows	Index (e) @ 30 Blows
1.	21	21.7	20.5	19	0.146	0.614	0.548
2.	21	21.2	20.75	20	0.042	0.305	0.267
3.	21	21.5	20.7	20.5	0.105	0.366	0.132
4.	21	21.9	20.9	20.5	0.188	0.121	0.110

TABLE IX

INDEX (e) VALUES OF LL=22 AT 20, 26 & 30 NUMBER OF BLOWS

S. No.	LL	W @ 20 Blows	W @ 26 Blows	W @ 30 Blows	Index (e) @ 20 Blows	Index (e) @ 26 Blows	Index (e) @ 30 Blows
1.	22	22.5	21.7	21	0.101	0.350	0.255
2.	22	22.3	21.6	20.5	0.0607	0.467	0.387
3.	22	23.1	21.8	21.5	0.2186	0.232	0.126
4.	22	22.23	21.85	21	0.0466	0.174	0.255
5.	22	22.5	21.9	21.65	0.102	0.116	0.088
6.	22	23.5	21.87	20	0.2955	0.151	0.522

TABLE X

INDEX (e) VALUES OF LL=24 AT 20, 26 & 30 NUMBER OF BLOWS

S. No.	LL	W @ 20 Blows	W @ 26 Blows	W @ 30 Blows	Index (e) @ 20 Blows	Index (e) @ 26 Blows	Index (e) @ 30 Blows
1.	24	25.1	23.7	22	0.200	0.321	0.477
2.	24	25.5	23.8	23.5	0.271	0.213	0.115

TABLE XI

INDEX (e) VALUES OF LL=26 AT 20, 26 & 30 NUMBER OF BLOWS

S. No.	LL	W @ 20 Blows	W @ 26 Blows	W @ 30 Blows	Index (e) @ 20 Blows	Index (e) @ 26 Blows	Index (e) @ 30 Blows
1.	26	26.5	25.7	25	0.085	0.296	0.296
2.	26	27.3	25.8	23.5	0.218	0.196	0.196
3.	26	28	25.88	24	0.332	0.118	0.118
4.	26	26.85	25.92	25.80	0.144	0.078	0.078

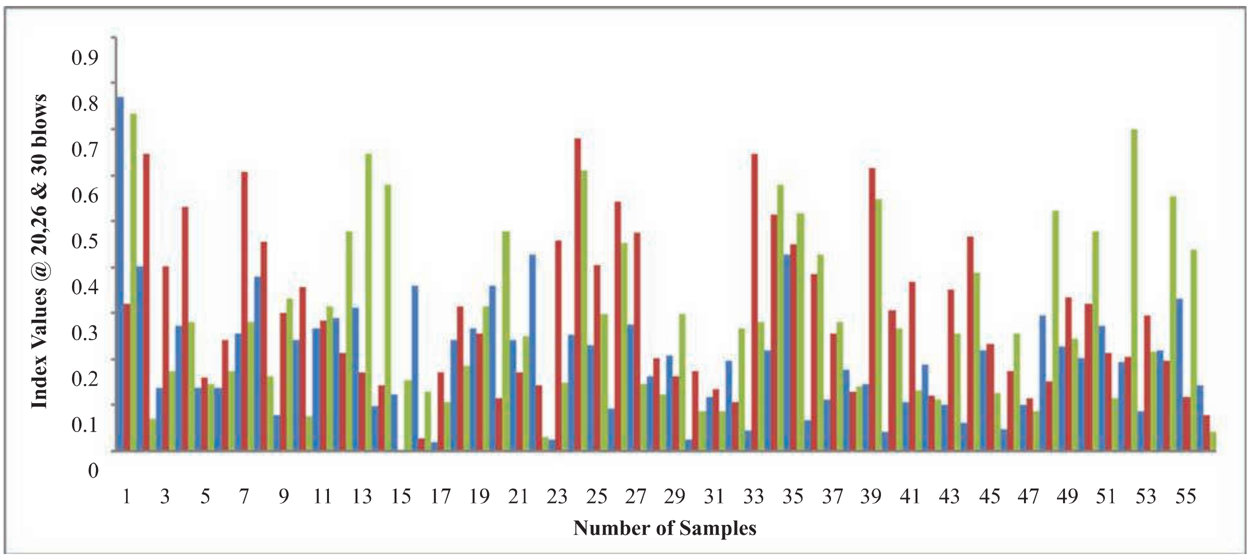

Fig. 5. All 56 Index (e) values @ 20, 26 & 30 Number of Blows

B. Index (e) values for soil specimens

The most appropriate value of index can be calculated by finding out the average of available index values at selected number of blows.

The average value of index (e) at 20 number of blows = e_{20}= 0.20393

The average value of index (e) at 26 number of blows = e_{26}= 0.29301

The average value of index (e) at 30 number of blows = e_{30}= 0.29131

The average of these three values of index (e) will finally give the required value:

$e_{RK} = (e_{20} + e_{26} + e_{30}) / 3$

$e_{RK} = (0.20393+0.29301+0.29131) / 3$

$e_{RK} = 0.26275$

$e_{RK} = 0.263$

IV. VALIDATION

After the computation of the index (e) values at 20, 26 and 30 number of blows, the values are utilized to compute liquid limit values using one point formula and to validate the reliability. The values of liquid limit and index (e) at 20, 26 and 30 number of blows are explained in Tables XII, XIII, and XIV, respectively. The graphical comparison of liquid limit and index (e) at 20, 26 and 30 number of blows are shown in Figs. 6, 7 and 8, respectively.

TABLE XII
COMPARISON OF LIQUID LIMIT BY ONE POINT & EXPERIMENTAL RESULTS @ 20 BLOWS

No.	W	N	e @ 20 Blows	LL by One Point Value	LL by Exp: Results
1.	19	20	0.263	17.91704	16
2.	17.5	20	0.263	16.50254	16
3.	16.5	20	0.263	15.55953	16
4.	17	20	0.263	16.03104	16
5.	16.5	20	0.263	15.55953	16
6.	16.5	20	0.263	15.55953	16
7.	18	20	0.263	16.97404	17
8.	18.5	20	0.263	17.44554	17
9.	17.3	20	0.263	16.31394	17
10.	19	20	0.263	17.91704	18
11.	19.1	20	0.263	18.01134	18
12.	19.2	20	0.263	18.10564	18
13.	19.3	20	0.263	18.19994	18
14.	18.4	20	0.263	17.35124	18
15.	18.5	20	0.263	17.44554	18
16.	19.5	20	0.263	18.38854	18
17.	18.08	20	0.263	17.04948	18
18.	19	20	0.263	17.91704	18
19.	19.1	20	0.263	18.01134	18
20.	19.5	20	0.263	18.38854	18
21.	19	20	0.263	17.91704	18
22.	19.8	20	0.263	18.67144	18
23.	18.1	20	0.263	17.06834	18
24.	20.1	20	0.263	18.95434	19
25.	20	20	0.263	18.86004	19
26.	19.4	20	0.263	18.29424	19
27.	20.2	20	0.263	19.04864	19
28.	19.7	20	0.263	18.57714	19
29.	19.9	20	0.263	18.76574	19
30.	19.1	20	0.263	18.01134	19
31.	19.5	20	0.263	18.38854	19
32.	19.85	20	0.263	18.71859	19
33.	20.2	20	0.263	19.04864	20
34.	21	20	0.263	19.80304	20
35.	22	20	0.263	20.74605	20
36.	20.3	20	0.263	19.14294	20
37.	20.5	20	0.263	19.33154	20
38.	20.8	20	0.263	19.61444	20
39.	21.7	20	0.263	20.46315	21
40.	21.2	20	0.263	19.99164	21
41.	21.5	20	0.263	20.27455	21
42.	21.9	20	0.263	20.65175	21
43.	22.5	20	0.263	21.21755	22
44.	22.3	20	0.263	21.02895	22
45.	23.1	20	0.263	21.78335	22
46.	22.23	20	0.263	20.96294	22
47.	22.5	20	0.263	21.21755	22
48.	23.5	20	0.263	22.16055	22
49.	24.2	20	0.263	22.82065	23
50.	25.1	20	0.263	23.66935	24
51.	25.5	20	0.263	24.04655	24
52.	26.1	20	0.263	24.61236	25
53.	26.5	20	0.263	24.98956	26
54.	27.3	20	0.263	25.74396	26
55.	28	20	0.263	26.40406	26
56.	26.85	20	0.263	25.31961	26

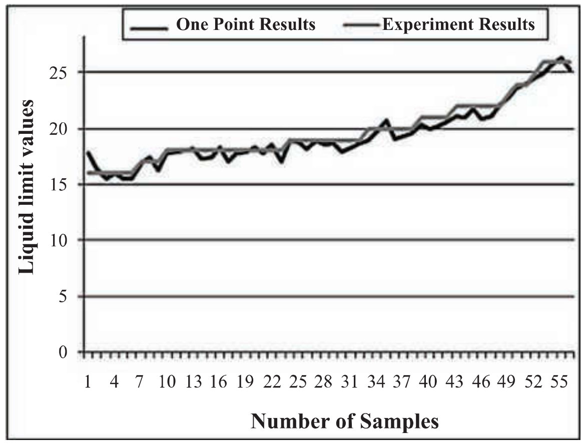

Fig. 6. Comparison of LL b/w One Point & Experimental Results @ 20 number of Blows

TABLE XIII
COMPARISON OF LIQUID LIMIT BY ONE POINT & EXPERIMENTAL RESULTS @ 26 BLOWS

No.	W	N	e @ 20 Blows	LL by One Point Value	LL by Exp: Results
1.	15.8	26	0.263	15.96382	16
2.	15.6	26	0.263	15.76175	16
3.	15.75	26	0.263	15.9133	16
4.	15.67	26	0.263	15.83247	16
5.	15.9	26	0.263	16.06486	16
6.	15.85	26	0.263	16.01434	16
7.	16.6	26	0.263	16.77212	17
8.	16.7	26	0.263	16.87315	17
9.	16.8	26	0.263	16.97419	17
10.	17.75	26	0.263	17.93404	18
11.	17.8	26	0.263	17.98456	18
12.	17.85	26	0.263	18.03508	18
13.	17.88	26	0.263	18.06539	18
14.	17.9	26	0.263	18.08559	18
15.	18	26	0.263	18.18663	18
16.	17.98	26	0.263	18.16642	18
17.	17.88	26	0.263	18.06539	18
18.	17.78	26	0.263	17.96435	18
19.	17.82	26	0.263	18.00477	18
20.	17.92	26	0.263	18.1058	18
21.	17.88	26	0.263	18.06539	18
22.	17.9	26	0.263	18.08559	18
23.	17.68	26	0.263	17.86331	18
24.	18.5	26	0.263	18.69182	19
25.	18.7	26	0.263	18.89389	19
26.	18.6	26	0.263	18.79285	19
27.	18.65	26	0.263	18.84337	19
28.	18.85	26	0.263	19.04544	19
29.	18.88	26	0.263	19.07576	19
30.	18.87	26	0.263	19.06565	19
31.	18.9	26	0.263	19.09596	19
32.	18.92	26	0.263	19.11617	19
33.	19.5	26	0.263	19.70218	20
34.	19.6	26	0.263	19.80322	20
35.	19.65	26	0.263	19.85374	20
36.	19.7	26	0.263	19.90426	20
37.	19.8	26	0.263	20.00529	20
38.	19.9	26	0.263	20.10633	20
39.	20.5	26	0.263	20.71255	21

40.	20.75	26	0.263	20.96514	21
41.	20.7	26	0.263	20.91463	21
42.	20.9	26	0.263	21.1167	21
43.	21.7	26	0.263	21.92499	22
44.	21.6	26	0.263	21.82396	22
45.	21.8	26	0.263	22.02603	22
46.	21.85	26	0.263	22.07655	22
47.	21.9	26	0.263	22.12707	22
48.	21.87	26	0.263	22.09676	22
49.	22.7	26	0.263	22.93536	23
50.	23.7	26	0.263	23.94573	24
51.	23.8	26	0.263	24.04677	24
52.	24.8	26	0.263	25.05714	25
53.	25.7	26	0.263	25.96647	26
54.	25.8	26	0.263	26.06751	26
55.	25.88	26	0.263	26.14833	26
56.	25.92	26	0.263	26.18875	26

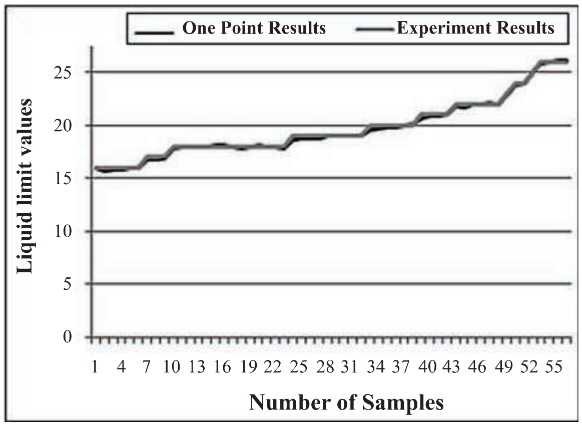

Fig. 7. Comparison of LL b/w One Point & Experimental Results @ 26 Number of Blows

TABLE XIV
COMPARISON OF LIQUID LIMIT BY ONE POINT & EXPERIMENTAL RESULTS @ 30 BLOWS

No.	W	N	e @ 20 Blows	LL by One Point Value	LL by Exp: Results
1.	14	30	0.263	14.68766	16
2.	15.8	30	0.263	16.57608	16
3.	15.5	30	0.263	16.26134	16
4.	15.2	30	0.263	15.94661	16
5.	15.58	30	0.263	16.34527	16
6.	15.5	30	0.263	16.26134	16
7.	16.15	30	0.263	16.94327	17
8.	16.5	30	0.263	17.31046	17
9.	16	30	0.263	16.7859	17
10.	17.75	30	0.263	18.62186	18
11.	17	30	0.263	17.83502	18
12.	16.5	30	0.263	17.31046	18
13.	16	30	0.263	16.7859	18
14.	16.2	30	0.263	16.99572	18
15.	17.5	30	0.263	18.35958	18
16.	17.58	30	0.263	18.44351	18
17.	17.65	30	0.263	18.51695	18
18.	17.4	30	0.263	18.25467	18
19.	17	30	0.263	17.83502	18
20.	16.5	30	0.263	17.31046	18
21.	17.2	30	0.263	18.04484	18
22.	17.9	30	0.263	18.77923	18
23.	17.52	30	0.263	18.38056	18
24.	17	30	0.263	17.83502	19
25.	18	30	0.263	18.88414	19
26.	17.5	30	0.263	18.35958	19
27.	18.5	30	0.263	19.4087	19
28.	18.58	30	0.263	19.49263	19
29.	18	30	0.263	18.88414	19
30.	18.7	30	0.263	19.61852	19
31.	18.7	30	0.263	19.61852	19
32.	18.1	30	0.263	18.98905	19
33.	19	30	0.263	19.93326	20
34.	18	30	0.263	18.88414	20
35.	18.2	30	0.263	19.09396	20
36.	18.5	30	0.263	19.4087	20
37.	19	30	0.263	19.93326	20
38.	19.5	30	0.263	20.45782	20
39.	19	30	0.263	19.93326	21
40.	20	30	0.263	20.98238	21
41.	20.5	30	0.263	21.50694	21
42.	20.58	30	0.263	21.59086	21
43.	21	30	0.263	22.03149	22
44.	20.5	30	0.263	21.50694	22
45.	21.5	30	0.263	22.55605	22
46.	21	30	0.263	22.03149	22
47.	21.65	30	0.263	22.71342	22
48.	20	30	0.263	20.98238	22
49.	22	30	0.263	23.08061	23
50.	22	30	0.263	23.08061	24
51.	23.5	30	0.263	24.65429	24
52.	22	30	0.263	23.08061	25
53.	25	30	0.263	26.22797	26
54.	23.5	30	0.263	24.65429	26
55.	24	30	0.263	25.17885	26
56.	25.8	30	0.263	27.06726	26

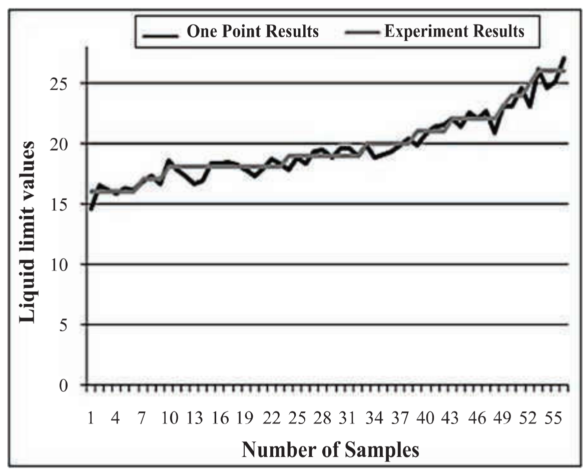

Fig. 8. Comparison of LL b/w One Point & Experimental Results @ 30 Number of Blows

A. Reliability of the results

To validate the reliability of the test results, the variance and standard deviation of results were also calculated. The difference of both quantities is represented in Fig. 9.

The Reliability @ 20 Blows = 87%.

The Reliability @ 26 Blows = 99.97%.

The Reliability @ 30 Blows = 99.94%.

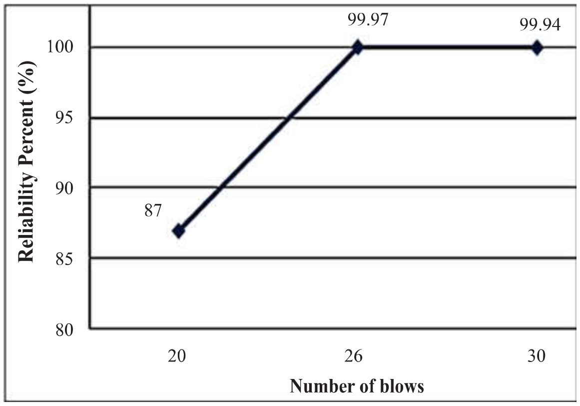

Fig. 9. Comparisons of Reliability of LL b/w One Point and Experimental Results @ 20, 26 & 30 Number of Blows

V. CONCLUSIONS

The purpose of this research work is to introduce the constant values of index (e) and Number of Blows for A-7-6 (AASHTO Classification) clayey shale type soils using one point formula. 100 samples of A-7-6 soil were collected from Jamshoro (Pakistan) zone and multi point Casagrande liquid limit laboratory tests were performed. The 20-30 number of blows were determined as best in the light of literature and placed constant for One Point Formula. Experimental results were validated with one point formula results and an excellent relationship was observed. The index (e) value obtained by this research was found different form that suggested by Punmia et al. (2005) (ranging between 0.068-0.121) [xviii]. The calculated value was verified on all collected samples and fairy accurate results were obtained using this index (e) value. Based on the laboratory investigation and research work, it was found that for Jamshoro soil, the Index value (eRK) is 0.263. This evaluated index value and calculated quantity of number of blows will help the user to avoid performing liquid limit laboratory tests on proposed soil.

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