IOP Conf. Series: Materials Science and Engineering **433** (2018) 012030 doi:10.1088/1757-899X/433/1/012030

Assessment of accuracy in determining Atterberg limits for four Iraqi local soil laboratories

H O Abbas [1]
[1]Department of Civil Engineering, College of Engineering, University of Diyala, Iraq
temimi71@yahoo.com

Abstract: The determination of Atterberg limits has large benefits in term of the classification of soil. Thus, it is necessary to obtain high accuracy in determination of these Atterberg limits, and the Atterberg limits test is considered an essential soil test. This study is focused on evaluation of results from four local laboratories, here labelled A, B, C and D based on sending two different type of soil to each laboratory. It was concluded from this study there may be large differences in determining Atterberg limits of as much as 17% for the same sample in the same laboratory. The accuracy of different laboratories in terms of measuring Atterberg limits differed widely. In general, laboratory B was the best followed by C, D then A. The percent of relative error in plasticity index value depend on the relative error product when determining Atterberg limits.

KEYWORDS: Atterberg limits, Accuracy of laboratories, Plasticity index.

1. Introduction

The physical properties of fine grained soils can be explained by their consistency limits. Index properties such as the liquid limit (LL, w_L) and plastic limit (PL, w_p) are thus frequently used to determine certain engineering properties of fine-grained soils. The method for determining w_L is a mechanical process, Norsk Standard NS 8002-1982 [4], and the probability of errors happening during measurement is not significant. This is not the case, however for the method used to determine the w_p of fine grained soils, although the current method of measurement is certified by many standards across the world including Norsk Standard NS 8003-1982 [5]. The procedure in question depends on a fairly crude technique known largely as the thread rolling test, which has been the subject of much critique in recent years. Researchers have studied the main problems related to the standard determination of w_p and, in an attempt to enhance accuracy, have developed several amended methods. Many of these are dependent on the cone penetration procedure used for w_L tests, with the aim of creating a method that is more nuanced and generally repeatable when carried out under the same conditions. The value of the plasticity index PI can be determined from liquid and plastic limits (PI = w_L - w_p). PI is used in classification of soil and used in conjunction with some engineering soil properties, such as soil strength, as shown in Figure (1). Consistency is used to describe the degree of stiffness of a soil in qualitative methods by using descriptions such as soft, medium, stiff or hard. The physical properties of fine grained soils are generally affected by the amount of water with in them and depending on the value of water content in the soil, the following four stages of states of consistency are used to describe the consistency of fine-grained soil: a. the liquid state; b. the plastic state; c. the semi-solid state; and d. the solid state (6). The water content levels at which a fine-grained soil undergoes a change from one state to another are called consistency limits. The Swedish scientist Atterberg originally defined seven limits of consistency to classify fine-grained soils, but engineering practice only tends to use two of these limits widely the liquid and plastic limits. The w_p is the water content that defines where the soil changes from a semi-solid to a plastic state while the w_L is the moisture content that defines where the soil changes from a plastic to a viscous fluid state. Methods for measuring w_L and w_p are listed in different standards. Norsk Standard NS 8002-1982[4] defines the consistency limits, terms and symbols while Norsk Standard NS 8003-1982 (5] defines the apparatus, procedures and determination of w_L using a fall cone. Norsk Standard NS 8003-1982[5] defines the laboratory method for determining w_p.

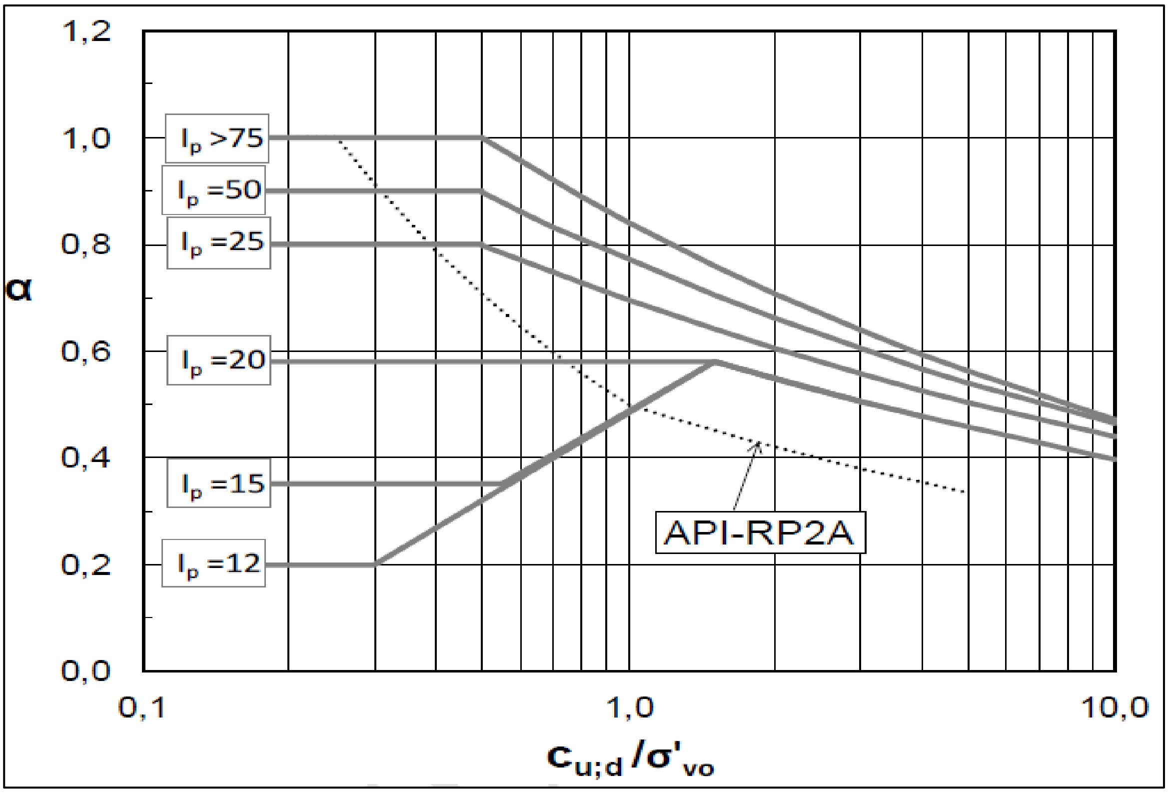

Figure 1. Recommended Procedure for Determining the Normalized Side Friction in Clay (α) and Ratio of Undrained Cohesion (C_U) to Effective Overburden Pressure (σ_{vo}) [6].

Determining the plastic limit, w_p, and liquid limit, w_L are called the Atterberg limits tests. These tests are used to determine the consistency of clay, and used to characterise the fine-grained fractions of soils either individually or together with other soil properties, in an attempt to correlate these features with engineering properties such as compressibility, permeability, swell shrink and shear strength [6]. In light of the importance of Atterberg limits and plasticity index results and the limited knowledge currently available in terms of the accuracy of results determining Atterberg limits in different laboratories, the present study is an attempt to evaluate the results of Atterberg limits in four local geotechnical laboratories (A, B, C, and D) to develop further understanding.

2. Experimental Work

Two different disturbed samples were obtained from the Al-Khalis region and Al-Anbar Governorate/Bushayrah Valley, 35 kilometres south of Al-Waleed Military Base. The two types of soil were cleaned and sieved on sieve No.40. Each soil was inspected to ensure exactly homogeneity and divided into eight parts which were labelled and put into nylon bags as shown in Figure (2**).**

IOP Conf. Series: Materials Science and Engineering **433** (2018) 012030 doi:10.1088/1757-899X/433/1/012030

Figure 2. Labelled Samples to be Sent to Laboratories (A, B, C and D).

After that, the samples of both types of soil were sent to four local laboratories in Iraq**.** Atterberg limits tests were then carried out in laboratories A, B, C and D. To achieve a statistical analysis of Atterberg limits testing for the four local laboratories, the author carried out four attempts to test the Atterberg limits for each sample of soil 1 and soil 2, (denoted lab. R). After that, the average of the four trials was calculated and taken to denote the real or exact results. These four trials are shown in Table (1) which displays the good accuracy and low difference levels among these trials.

Table 1. Results of Atterberg Limits and Plasticity Index in Lab. R.

Sample No. / Type of test	Soil 1					Soil 2				
	Trial 1	Trial 2	Trial 3	Trial 4	Average	Trial 1	Trial 2	Trial 3	Trial 4	Average
Liquid limit	34.8	35.2	35.4	35.7	35.3	126	125	126	124	125.3
Plastic limit	21	21.4	21.9	21.8	21.5	45	46	47	45	45.8
Plasticity index	13.8	13.8	13.5	13.9	13.8	81	79	79	79	79.5

3. Soil Classification

Initially, grain size distribution tests were carried out on the two soils. The first soil was classified as sandy soil with clay well graded (SW-SC). The grain size distribution of soil 1 is shown in Figure (3); its coefficient of uniformity Cu=8.5 and curvature Cc=1.06. The second soil was washed during sieving because it had a large quantity of clay and was classified as clay of high plasticity (CH). The grain size distribution is shown in Figure (4) and the percent of clay in soil 2wais 82%.

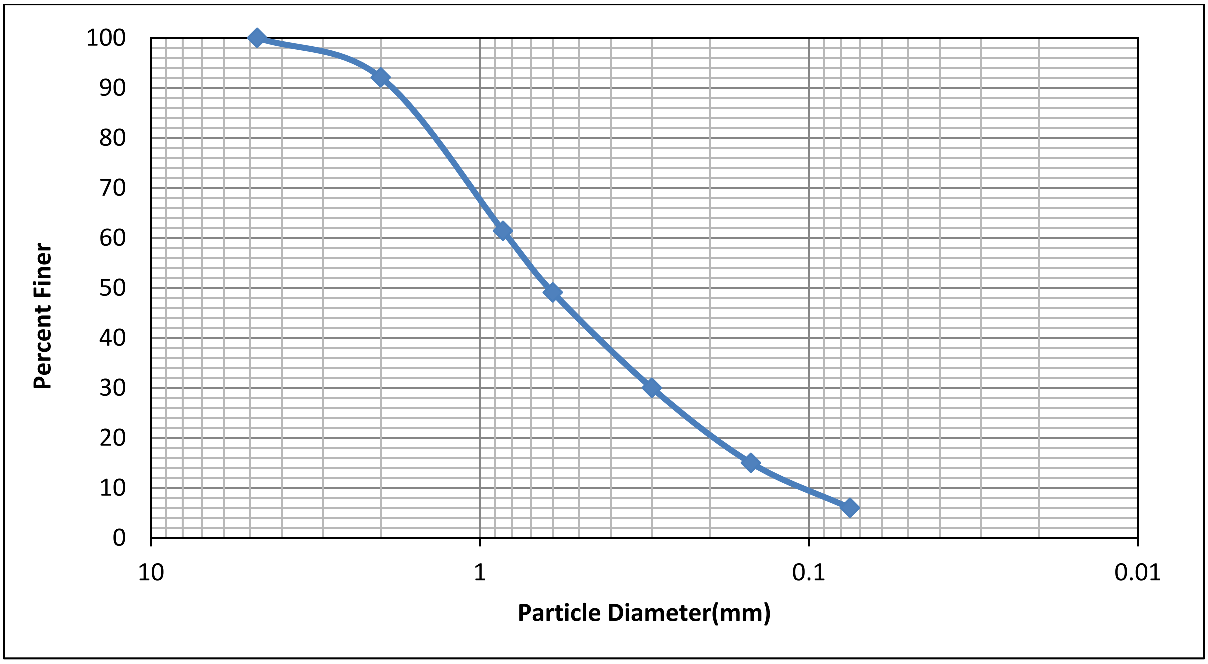

Figure 3. Grain Size Distribution of Soil 1.

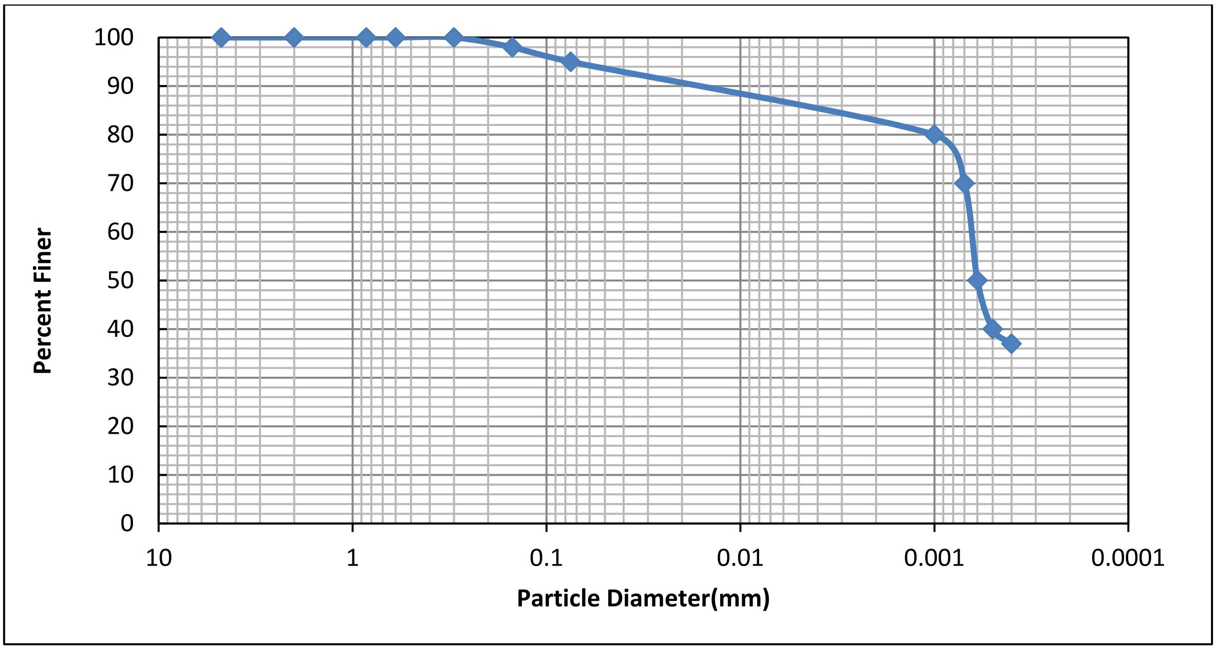

Figure 4. Grain Size Distribution of Soil 2.

4. Results and Discussion

The results of liquid limit and plastic limit tests were obtained for the two soils from four laboratories (A, B, C, and D). The plasticity index was calculated as the difference between the liquid and plastic limits. All the results in addition to results of lab(R) are shown in Table (2). Statistical analysis was used to determine the average, standard deviation and coefficient of variation for the liquid and plastic limits and plasticity index of two sample soils. Table (3) shows the summary of the statistical analysis, that allows conclusion of the following points.

4.1Comparison among the results of two sample soils:

It is clear from results in Table (3) that the standard deviation and coefficient of variation of the Atterberg limits and plasticity index for soil 2 were greater than soil 1. This means that the results of soil 2 contain more errors than those for soil 1. This is due to the nature of the soil as its high plasticity is more sensitive to changes in water content, which causes difficulties in control of water content during experimentation. In general, the plastic limit and plasticity index have greater standard deviations and coefficients of variation than the liquid limit for both types of soil. Where the soil contains lower amount of clay, the Atterberg limits have a lower standard deviation and coefficient of variation. The presence of large quantities of clay in the soil causes a higher probability of errors in the determination of Atterberg limits.

Table 2. Summary of Atterberg Limits Results of Four Laboratories.

Lab. Name	Soil 1						Soil 2					
	Liquid Limit		Plastic Limit		Plasticity Index		Liquid Limit		Plastic Limit		Plasticity Index	
A	33.9	35.8	23.6	24.2	10.3	11.6	117.7	132.3	95.9	87.7	21.8	44.6
B	36.1	36.95	18.74	20.26	17.36	16.68	127.97	120.81	33.56	39.7	94.4	81.11
C	35.1	37.83	22.2	22.03	12.9	15.79	124.4	107.76	60.86	59.01	63.57	48.75
D	38	37.1	23	26.1	15	11	130	122.5	74.6	65.5	55.4	57
R	35.3		21.5		13.80		125.3		45.8		79.5	

Table 3. Summary of the Statistical Analysis of Results of Laboratories.

	Soil 1						Soil 2					
	Liquid Limit		Plastic Limit		Plasticity Index		Liquid Limit		Plastic Limit		Plasticity Index	
Average	36.3	36.3	22.5	22.5	13.8	13.8	122.9	122.9	64.6	64.6	58.3	58.3
Standard Deviation	1.73	0.84	2.17	2.54	3.01	2.88	5.40	10.09	26.12	19.79	29.84	16.33
Coefficient of Variation	4.78	2.31	9.66	11.31	21.80	20.89	4.39	8.29	40.43	30.64	51.18	28.01

4.2. Comparison among the accuracy of the laboratories (A,B,C,and D):

It is assumed that the average of results carried out in lab R as in Table (1) for the Atterbeg limits and plasticity indices of the two soils reflect the real or exact value. Therefore, the percentage of relative error was calculated for all results from the other laboratories as equal to the difference between the real value (average) and the laboratory result divided by the real value. Table (4) shows the percentage of relative error for all results.

Table 4. Summary of Percent of Relative Error for Laboratories Results.

Lab. Name	Soil 1						Soil 2					
	Liquid Limit		Plastic Limit		Plasticity Index		Liquid Limit		Plastic Limit		Plasticity Index	
A	3.97	1.42	9.77	12.56	25.36	15.94	6.07	5.59	109.39	91.48	72.58	43.90
B	2.27	4.67	12.84	5.77	25.80	20.87	2.13	3.58	26.72	13.32	18.74	2.03
C	0.57	7.17	3.26	2.47	6.52	14.42	0.72	14	32.88	28.84	20.04	38.68
D	7.65	5.10	6.98	21.4	8.70	20.29	3.75	2.23	62.88	43.01	30.31	28.30

The results for laboratory A, B, C, and D were then compared to assess which one was most accurate, as in the following points.

a. Differences in the results for the same sample in the same laboratory: Samples of soil 1 and soil 2 were repeated two times for all laboratories. In general, the difference of the two trials for the results of all laboratories in sample soil 2 is greater than in sample soil 1. The differences in the Atterberg limits ranged between 0.60% to 14.6 %, 0.85% to 7.16 %, 0.17% to 16.64 % and 0.90% to 9.10 % for laboratories A, B, C, and D respectively. According to this analysis, laboratory B showed fewer differences than the other laboratories. The preferential arrangement of laboratories is thus B, D, A, and C.

b. Differences in the results for the same sample in different laboratories: After determining the percentage of relative error and average of relative error for the Atterberg limits and plasticity indices calculated by each laboratory, results were obtained as shown in Figures 5, 6, and 7. Figure 5 shows that laboratory B gave a low percentage of relative error in terms of liquid limits as compared to the other laboratories. The arrangement of preferred laboratories is thus B, A, C, and D. Figure 6 shows that laboratory B also gave a low percentage of relative error in plastic limits as compared to other laboratories. The arrangement of preferred laboratories is thus B, C, D, and A. The percentage of relative error in plasticity index is tentatively calculated based on the relative error in the liquid and plastic limits. Figure 7 signifies that laboratory B gave a low percent of relative error in plasticity index as compared to other laboratories. The arrangement of the preferred laboratories is thus B, C, D, and A.

4.3. Comparison of classification of soil 1 and soil 2 from the results of laboratories:

It is obvious from the results of Atterberg limits tests from the four laboratories that their classification of soil 1 is identical SW-SC but differs for soil 2. In laboratories A, C, and D classified soil 2 as MH-OH while laboratory B classified it as CH. In reality, only the latter laboratory classification of soil 2 is correct, because the percentage of clay is 82% obtained from the hydrometer test. The results of the Atterberg limits and plasticity indices have an influence on the special classification of soil; in soil 2, the swelling potential is particularly high according to lab B and lab R while less swelling potential is accorded to it by other laboratories as shown in Figure 8.

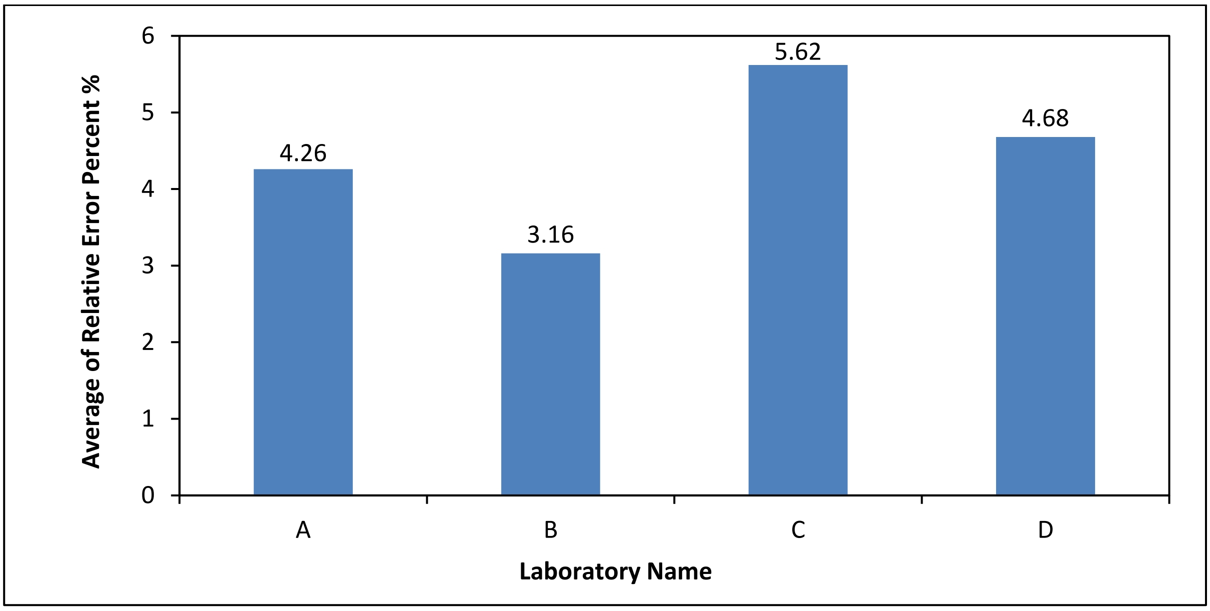

Figure 5. Percentage of Average of Relative Error in Determining Liquid Limit for Laboratories A, B, C, and D.

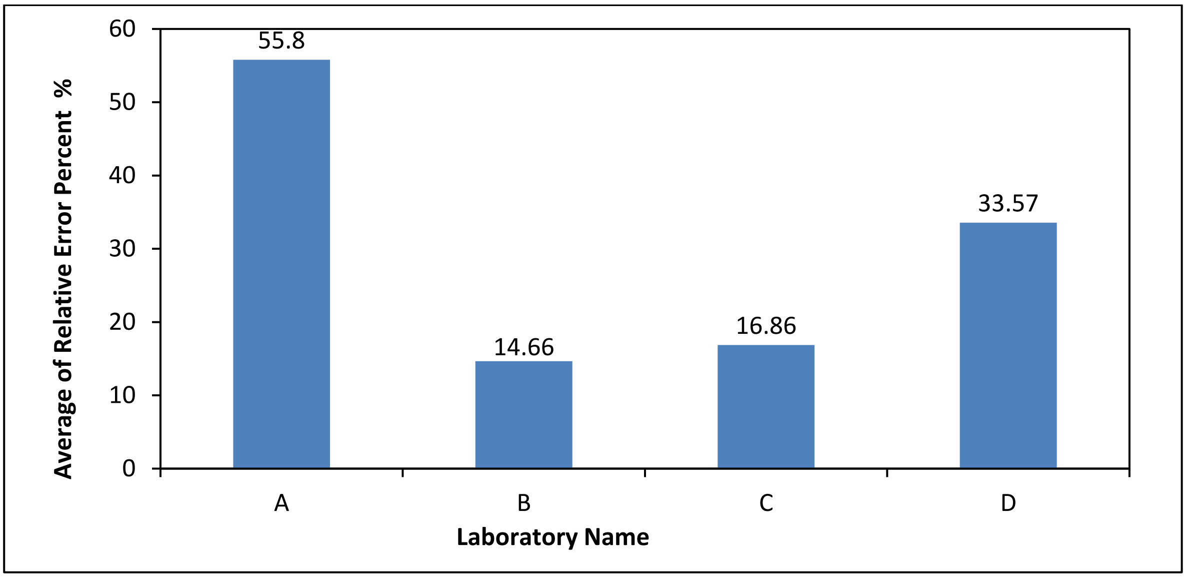

Figure 6. Percentage of Average of Relative Error in Determining Plastic Limit for Laboratories A, B, C, and D.

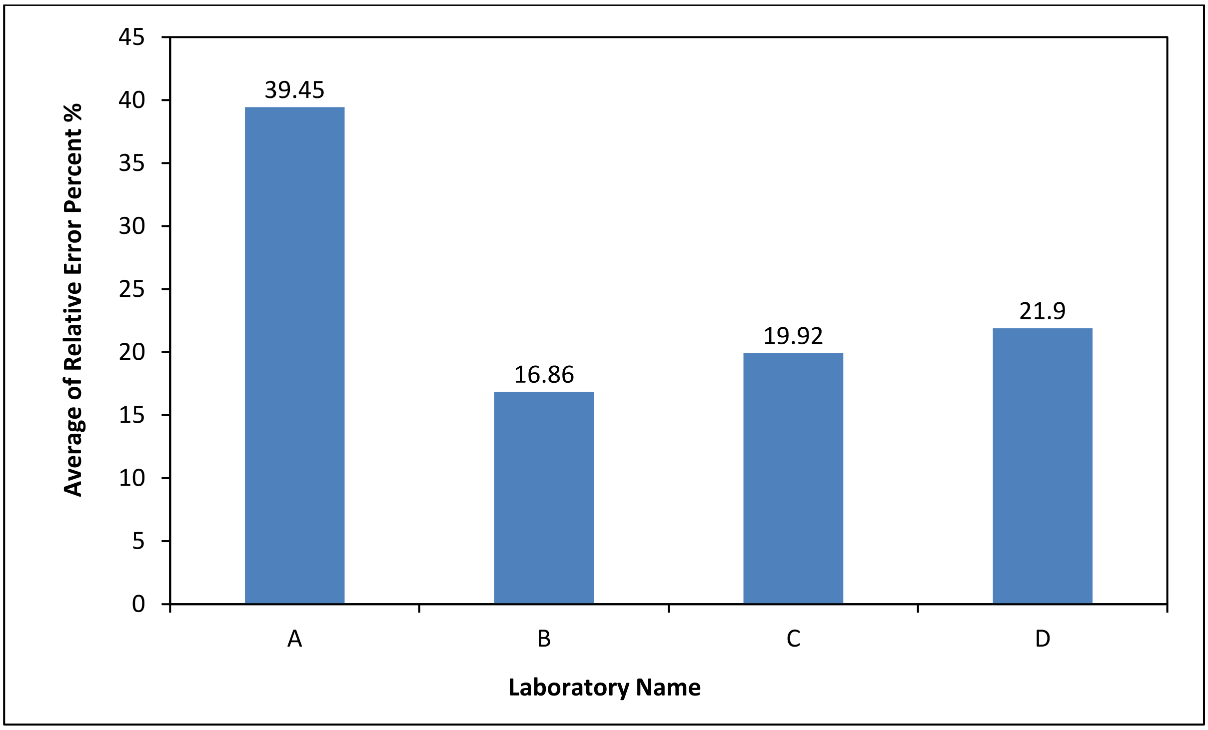

Figure 7. Percentage of Average of Relative Error in Determining Plasticity Index for Laboratories A, B, C, and D.

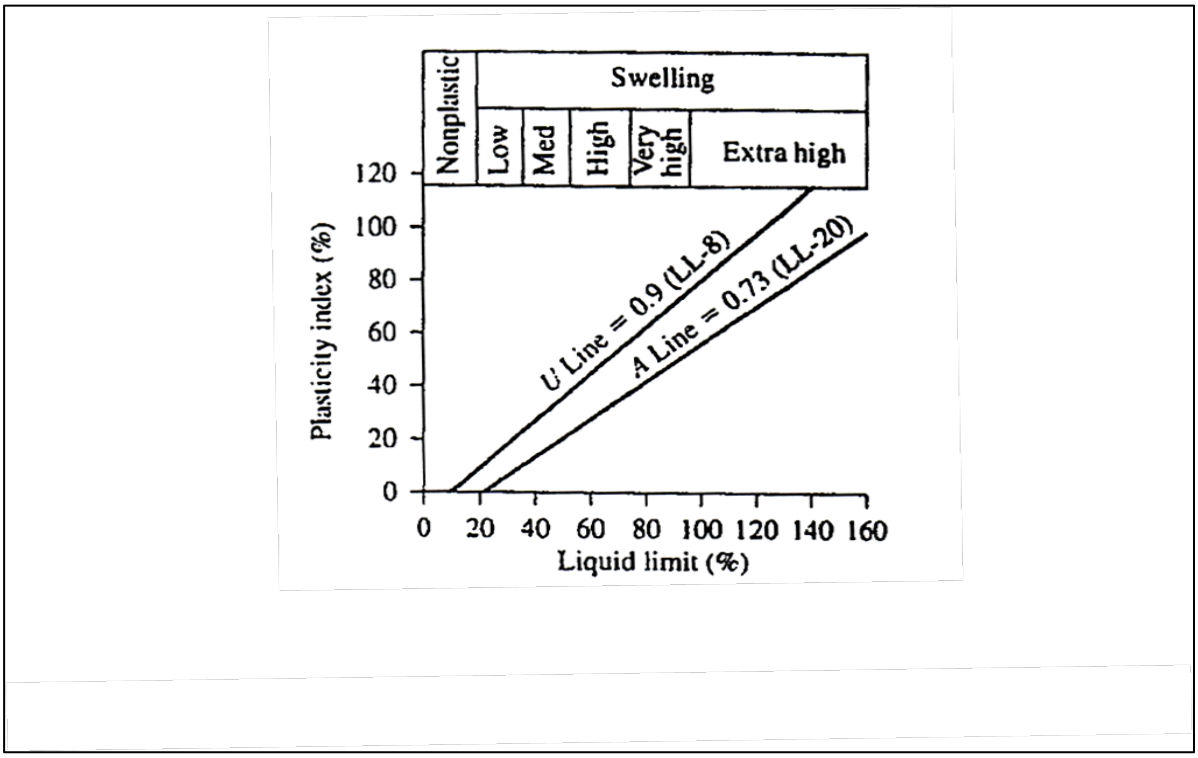

Figure 8. Classification Chart for Expansive Soil [3]

IOP Conf. Series: Materials Science and Engineering **433** (2018) 012030 doi:10.1088/1757-899X/433/1/012030

5. Conclusions

1. Type of soils has an effect on the accuracy of determining Atterberg limits. When the amount of clay present increases, the probability of error increases.

2. A large difference in determining Atterberg limits may exists, here seen as up to 17% for the same sample and laboratory.

3. The accuracy of different laboratories in measuring Atterbeg limits differs. In general, in this test laboratory B was the best followed by C, D and A.

4. The percentage of relative error in plasticity index value depends on the relative error product which determining Atterberg limits.

6. References

[1] ASTM D 4318-00 *Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.*

[2] ASTM D2487-00 *Standard Test Method for Classification of Soils for Engineering Purposes (Unified Soil Classification System).*

[3] Dakshanamurthy V and Raman V 1973 *A simple method of identifying an expansive soil* Soils and Foundations, Japanese Society on Soil Mechanics and Foundation Engineering **13** 1, pp. 79–104.

[4] NS 8002-1982 Geotechnical *testing Laboratory Methods Fall Cone Liquid Limit*.

[5] NS 8003-1982 Geotechnical *Testing Laboratory Methods Plastic Limit.*

[6] Sivakumar V, Henderson L, Moorhead C.M., Hughes, D and Sivakumar S 2011 *Measurements of the Plastic Limit of Fine Soils*: Further Development Submitted for publication to Géotechnique.