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LIQUID LIMIT DETERMINATION OF THE HIGH PLASTIC CLAYS BY ONE-POINT METHOD

SUMMARY: The high plastic clay is important material for preparation of sealing coats. The sealing coats are one of part in the waste disposal remediation. The classification of soils represents the first step towards further investigations of clays. Clay is classified using Atterberg's limits or plastic limits. It has been proved that the consistent state of the clay is functionally related to the moisture content. The liquid limit can be represented as a function of any other moisture and the respective number of bumps of the bowl of the Casagrande apparatus at that moisture. This paper proves the existence of that relation that is, however, the property of a certain classification group of materials for which it is necessary to determine the function exponent in the first place and subsequently to perform tests by the one-point method. The existing exponents from other Standards do not have to yield correct results.

DOLOČANJE MEJE ŽIDKOSTI VISOKO PLASTIČNIH GLIN Z METODO ENE TOČKE

POVZETEK: Visoko plastična glina je pomemben material za izdelavo tesnilnih pokrovov. Tesnilni pokrovi predstavljajo enega od ukrepov pri sanacijah deponij odpadkov. Klasifikacija zemljin predstavlja prvi korak k nadaljnjemu preiskovanju glin. Glino klasificiramo z uporabo Atterbergovih leznih mej ali mej plastičnosti. Znano je, da je konsistenčno stanje glin funkcijsko povezano z njeno vlažnostjo. Mejo židkosti lahko predstavimo kot funkcijo poljubne vlažnosti gline in ustreznega števila udarcev posodice Casagrandejevega aparata pri tej vlažnosti. Članek pokaže, da taka zveza obstaja, ki pa je odvisna od klasifikacije materiala. Za vsako vrsto materiala glede klasifikacije je potrebno najprej določiti funkcijski eksponent in šele nato lahko izvajamo preskuse z metodo ene točke. Trenutno veljavni eksponenti iz drugih Standardov ne dajejo pravilnih rezultatov.

INTRODUCTION

The determination of the plastic limit by the one-point method is standardized as follows: ASTM D 423-66 (renewed in 19729, DIN 18 122, C.P.S. Mode Operatoire G.-4(1964) and BS 1377 (1975). All these standards use the following expression for the computation:

$$w_L = w_N \left(\frac{N}{25} \right)^{tg\beta} \quad (1)$$

where the value of tgβ is taken according to recommendations by the U.S. Waterways Experiment Station (1949) as tgβ =0.12, whereas BS 1377 (1975) yields the value tgβ =0.092, bearing in mind that this value is for British soils. Mohan and Goel (1959) stated that coefficient tgβ is subject to variations. It was interesting to check this statement by a great number of samples that represent a statistically significant set. The paper deals only with liquid limits in clays of high plasticity (CH) with w_L>50% from various locations and with 47 of 88 samples taken from the same location. All samples were taken from the Dalmatian region (Croatia).

STATISTIC ANALYSIS OF THE FLOW CURVES

The statistic analysis was performed by two independent methods. It was proved, primarily, by using the χ^2 test, that the liquid limit for the set under consideration was a random variable that follows the law of normal distribution. In that case the statistical analysis was performed by analyzing and comparing the average values of the considered set and the sets used to prove stochastic similarity.

Average Value Method

In this approach it was necessary to compute the value of exponent tgβ for each of 88 curves, which was subsequently subjected to additional statistic analysis.

The equation of the flow curve is as follows:

$$w = a * N^{-tg\beta} \quad (2)$$

It is generally graphically represented in semilogarithmic graph, with logarithmic values on the abscise axis, so that it can be represented as a line. This can be explained by the fact that in the laboratory the line is visually passed through four points in order to determine the moisture content at the liquid limit for N=25 bumps of the standard bowl.

The computation of the tgβ exponent was performed by employing the linear regression method and using the equation of the line passing through four points, obtained in the laboratory, for 88 flow curves, which is:

$$\ln w = \ln a + tg\beta * \ln N \quad (3)$$

These data were used for the statistic analysis. The results are presented in Table 1.

Table 1 shows that, in this case, the value obtained by DIN for the exponent tgβ reaches its maximum, whereas its minimum is 0,023.

Further statistical analysis can prove that the curve of normal distribution is well suited for this set including 88 values of tgβ. The testing of hypothesis H_0 was performed by the χ^2 test which for 19 classes yielded the probability value according to Equation (3):

$$P\{\chi^2 > \chi_0^2\} = 0,63 \quad (4)$$

Table 1. The results of the statistical analysis which includes 88 values for tgβ for clays with $w_L > 50\%$

VARIABLE	tgβ
SAMPLE SIZE	88
AVERAGE	0.06314
MEDIAN	0.06193
MODE	0.06186
GEOMETRIC MEAN	0.05928
VARIANCE	0.000487
STANDARD DEVIATION	0.02207
STANDARD ERROR	0.00235
MINIMUM	0.02285
MAXIMUM	0.13225
RANGE	0.10940

Consequently, it can be concluded that the value of parameter tgβ is a variable of random distribution and that the statistically obtained values from Table 1 can be accepted for the moisture computation at the liquid limit w_L, by using one-point test.

Linear Regression Method

This method used a set of 88 flow curves, each with four points, i. e. a set with 352 points. In order to consider the set unambiguously, considering parameter tgβ, it was necessary to standardize the flow curve. This was performed by dividing each moisture value from each curve by the respective moisture at the liquid limit w_L. The flow curve contained now four points of the following type:

$$\frac{w_N}{w_{LL}} \tag{5}$$

A curve of the following type was passed through that set by the linear regression method:

$$w = a * N^{tg\beta} \tag{6}$$

which obtained the same method as in the case of individual flow curves, presented by equation (2). Figure 1 is a graphical representation of a set of normalized points through which a regression curve was passed by the linear regression methods. The Figure also presents the limits that include 95% and 90% of all data.

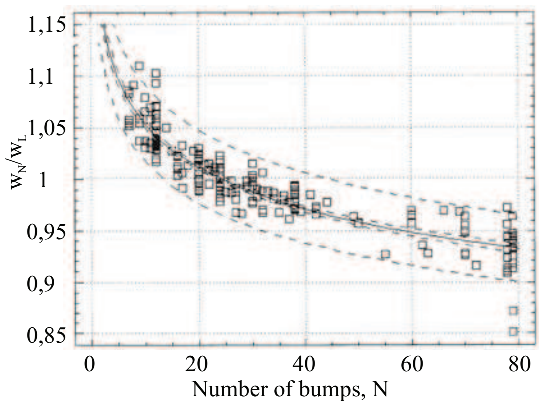

Figure 1 Regression curve passed through a set of normalized points from the measured flow curves obtained by four points

The results of this analysis are presented in Table 2.

Table 2. The results obtained by the analysis of the flow curves for clays of high plasticity, w_L > 50% by the linear regression method

SAMPLE SIZE	88
PARAMETER tgβ	0.06226
CORRELATION COEFFICIENT r	0.9103
r^2	0.8286

If we compare the values of the required exponent tgβ obtained in this way with those obtained by the average value method, the difference appears to be insignificant. The value of 0,063 will be adopted for further analyses.

COMPARISON WITH DIN STANDARDS

In order to establish the difference between the values obtained by the determination of the flow curve according to the analyzed curve and those obtained by using exponent tgβ from DIN, it was necessary to carry out computations for all existing data. The data were grouped according to the "points" of origin. Since each analyzed curve was formed by four points, four sets of data were created, each of them representing a set of respective points for all 88 curves. Subsequently, each set was used to compute the flow curve by one-point method taking into account either the exponent obtained by these analyses or the exponent recommended by DIN. The results are presented in the next table;

Table 3. Average values of the sets of liquid limits obtained by one - point with two different exponents

POINT	Number of bumps N FROM - TO	w_L%	
		tgβ = 0.121	tgβ = 0.063
1	7-12	55.92	58.51
2	12 - 28	57.86	58.54
3	20 - 39	59.63	58.76
4	41 - 79	62.08	58.76

In order to verify the results more accurately it should be stated that the average value of the liquid limit was obtained in the laboratory by the four - point method w_L = 58,7 %.

The adaptability of each set of results obtained by the determination of the liquid limit by the one point method with the DIN exponent, was tested regarding the results obtained by this analysis and those obtained by the 4 point method. This was performed by a t-test of acceptability or rejection of the H_0 hypothesis on the equality of the average values of the considered sets. Table 4 presents the results.

From the above Table it is evident that the adaptability of results obtained by the exponent is much better than the adaptability of results obtained by this analysis. The former method does not have to ensure such moisture of the sample that the number of drops approaches 25, whereas is DIN recommends to take that factor into account. The above analysis explains this requirement.

CONCLUSION

In summing up the previously presented facts is possible to draw three conclusions:
The one-point method for computing the plastic limit can be successfully applied when a great number of samples must be processed over a short time period.

It is not recommendable to use parameter tgβ from the current standards, since the above analyses show that the group of samples belonging to the same classification group has a certain value of parameter tgβ, which can significantly differ from the value recommended by DIN.

Before using the method it is necessary to determine the flow curves on a certain number of samples from which exponent tgβ will be defined for further application. A set of at least 10 samples is recommended.

Table 4. Results of the t - test: acceptance or rejection of the H_0 hypothesis on the equality of the average of the two sets

SAMPLE 1	SAMPLE 2	H_0
DIN, point 1	ACCORDING TO AUTHOR, point 1	REJECTED
DIN, point 2	ACCORDING TO AUTHOR, point 2	ACCEPTED
DIN, point 3	ACCORDING TO AUTHOR, point 3	ACCEPTED
DIN, point 4	ACCORDING TO AUTHOR, point 4	REJECTED
DIN, point 1	4 POINTS METHOD	REJECTED
DIN, point 2	4 POINTS METHOD	ACCEPTED
DIN, point 3	4 POINTS METHOD	ACCEPTED
DIN, point 4	4 POINTS METHOD	REJECTED
ACCORDING TO AUTHOR, point 1	4 POINTS METHOD	ACCEPTED
ACCORDING TO AUTHOR, point 2	4 POINTS METHOD	ACCEPTED
ACCORDING TO AUTHOR, point 3	4 POINTS METHOD	ACCEPTED
ACCORDING TO AUTHOR, point 4	4 POINTS METHOD	ACCEPTED

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