STUDY OF COMPATIBILITY OF METHODS FOR LIQUID LIMIT MEASUREMENT ACCORDING TO CZECH STATE STANDARD AND NEWLY ADOPTED EUROPEAN STANDARD

STUDIE KOMPATIBILITY METOD PRO MĚŘENÍ VLHKOSTI NA MEZI TEKUTOSTI DLE ČSN A NOVĚ PŘIJÍMANÉ EVROPSKÉ NORMY

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Abstract

The goal of the publication is a correlation between the methodology of liquid limit determination using Casagrande bowls according to the Czech state standard being valid as yet and the methodology on a principle of the conical test according to a newly adopted European standard. It allows a better link of utilization of an extensive statistical set of investigations realized for purposes of foundation engineering in past that are available in Geofond for newly conducted engineering geological studies according to the new European standard related to water contents at the liquid limit for wide-spread clay soils. The sample values ranged from 21.49 to 49.56 % according to Casagrande and in the conical test they ranged from 24.11 to 51.07 %. The difference of the results for identical samples reached values from 1.15 to 4.19 %. The studied mean difference coefficient between methods amounts to 2.55 %.

Abstrakt

Cílem publikace je studium korelace mezi metodikou stanovení vlhkosti na mezi tekutosti pomocí Casagrandeho misek dosud platné české státní normy a metodikou založenou na principu kuželové zkoušky dle nově implementované evropské normy. To umožní lepší návaznost využití rozsáhlého statistického souboru průzkumů realizovaných pro účely zakládání staveb v minulosti, které jsou k dispozici v Geofondu, na nově prováděné inženýrskogeologické průzkumy dle nové evropské normy v souvislosti s vlhkostí na mezi tekutosti pro velmi rozšířené jílovité zeminy. Rozpětí hodnot u zjištěných vzorků se pohybovalo od 21,49 do 49,56 % dle Casagrandeho a u kuželové zkoušky se pohybovalo v hodnotách od 24,11 do 51,07 %. Rozdíl výsledků u identických vzorků dosahoval hodnot od 1,15 do 4,19 %. Studovaný průměrný rozdílový koeficient mezi metodami má hodnotu 2,55 %.

Key words: liquid limit measurement, compatibility of standards, engineering geology, Ostrava Basin

1   INTRODUCTION

The goal of the study is to analyze a correlation between the methodology of the liquid limit measurement using Casagrande bowls according to CSN and the methodology on the principle of the conical test according to the European standard. It would allow a better compatibility and link of utilization of an extensive statistical set of investigations realized for purposes of foundation engineering related to the liquid limit.

In the first stage a comparative study has been carried out of both above mentioned methodologies, which represent a theoretical basis for subsequently realized laboratory works.

Within Ostrava Basin after specifying localities a sampling of fine grained soils was performed. The subsequent study in laboratories of the firm K - GEO was focused on laboratory tests of the taken samples by the methods of Casagrande bowls and conical test.

In the last stage a comparative analysis was realized to determine a correlative dependence which is an important aid for engineering geological practice.

2   ESSENTIAL TERMINOLOGY AND STANDARDS SUBJECT

The following technical specifications describe the test methods for determination of consistency limits of soil. Cohesive soils are mixtures of clay, dust and sandy grains. In nature they can contain bound and free water. The quantity of bound water increases in soil with a portion and type of a clay mineral and exchangeable cations. Moisture-dependant physical condition of cohesive soil is a so-called consistency condition. *Consistency limits* are liquid limit, plastic limit and shrinkage limit. These limits are called as "consistency or Atterberg limits" (according to a Norwegian specialist Atterberg who first used them for characterizing soils.

Liquid limit is understood to be soil moisture expressed in % of mass of dried soil (i.e. soil dried at the temperature from 100 to 110°C) to a constant mass, when the soil changes from plastic to liquid state. A test sample can be acquired from natural soil or from soil from which a material caught during grading on a sieve of a mesh size of 0.4 mm (or the nearest), was removed. Within the standard cones are used with shapes of 60 g / 60° and 80 g / 30°.

Liquid limit w_L is an empirically determined water content for which the soil changes from a liquid to plastic state.

Plastic limit is the lowest water content of soil whereat the soil is plastic. The determination of the plastic limit is usually performed simultaneously with the determination of the liquid limit.

Plastic limit w_P is an empirically determined water content whereat the soil is so much dried it loses its plasticity.

Plasticity index I_P is an arithmetic difference between the liquid limit and the plastic limit of soil.

Liquidity index I_L is a difference of natural water content and the plastic limit in proportion to the plasticity index of soil..

Consistency index I_L is a difference of the liquid limit and natural water content of soil in proportion to its plasticity index.

Activity index I_A is a ratio of the plasticity index to the portion of the clay size fraction of soil.

Clay size fraction CF is a dry weight of grains with equivalent diameter equal to or less than 0.002 mm, divided by the total dry weight of a test sample (or by dry weight of a test sample after removing the coarse fraction).

Coarse fraction is particles of soil that are held on a sieve of mesh size of 4 mm.

The liquid limit w_L is determined through the use of Casagrande device or Vasiljev cone. Through the first method we determine the liquid limit when a sample of soil with a horizontal and smooth surface placed in the bowl of the device and divided by a grooving tool into two parts which need 25 hits of the bowl to the base to close the gap between them in a length of 12.5+-0.5 mm namely at a rate of 2 hits per second. A detailed procedure is imposed by the Czech state standard ČSN 72 1014 – Laboratory determination of liquid limit of soils. While using the cone such water content matches to the liquid limit whereat the smooth metal cone with a apex angle of 30° and weight of 80 g placed on a smooth surface of a sample sinks into a depth of 20 mm during five seconds by self-weight. The procedure is given in the new European standard ČSN CEN ISO/TS 17892/12: Geotechnical investigation and testing – Laboratory testing of soils – Part 12: Determination of consistency limits.

3   THEORY TO STANDARDS

3.1 Resumé of standards

3.1.1 ČSN 72 1014 Laboratory determination of liquid limit of soils

This technical specification describes in total three methods of determination of consistency limits, namely determination the liquid limit using a bowl in a standard way, determination of the liquid limit using a bowl by a one-point method and determination of the liquid limit using a cone (Vasiljev). Whereas the subject of the study according to an older standard was only to determinate the liquid limit through the use of a bowl by the one-point method which was used in past most, the method is specified in this section.

The soil in a preparatory stage gets dried in the open air, and then it is disintegrated by a rubber spatula and passed through a sieve of 0.5 mm. A portion of the soil which falls through the sieve from the total quantity of the entire sample is recorded.

To perform the test correctly it is necessary to set the device accurately and prepare carefully the sample.

Minimum weight of a soil for the one-point method is 50 g. Pugging should last at least 10 minutes. The water content of soil has to be such the cake of soil closes the gap after 25 hits of the bowl.

The soil will be then set to an airtight weighing bottle and aged at least for 24 hours under a usual room temperature. Immediately prior to test the soil is pugged for at least one minute.

From the pugged paste a part of soil is removed and put to the bowl on the place where the bowl bears against a bearing plate. The soil surface in the bowl has to be smoothed with a knife to a plane parallel with the bearing plate. The soil cake in the bowl should have in the highest point a maximum thickness of 1 cm. With a cutting knife (Fig. 1a) a groove is cut (squeezed) in the soil cake, whose axis goes through the centre of the bowl suspension (Fig. 1b). Then the device is turned on and the bowl with the cut soil cake is allowed to fall from the height of 1 cm on the bearing plate. The process needs to be interrupted in the instant when both cake halves join at the bottom of the groove to the required length of 12.5 mm (+-0.5 mm). The number of hits that were necessary both halves of soil cake to join is recorded. This number of hits N may not be higher than 30 and lower than 20, otherwise the test has to be repeated.

From both cake halves a soil sample is taken somewhere from the centre in the amount of about 10 g and placed to the air-sealed weighing bottle. For the sample water content will be determined according to the ČSN 72 1012 standard (Laboratory determination of soil water content).

During *assessment* the water content is assessed from the taken sample according to the ČSN 72 1012 standard matching to the appropriate number of hits of the bowl N. The liquid limit w_L is then determined according to the formula as follows:

$$w_L = w_N - \left(\frac{N}{25} \right)^{0,12}$$

where w_N is the water content related to the soil that joined after N hits,

0.12 is a tangent of the function line "water content - number of hits".

Moisture values at the liquid limit are set forth in integer percentage of dry weight.

As for the result of the liquid limit w_L it is necessary to note that it was determined by the one-point method and also the ratio from the total quantity of soil the grains of diameter of 0.5 mm take.
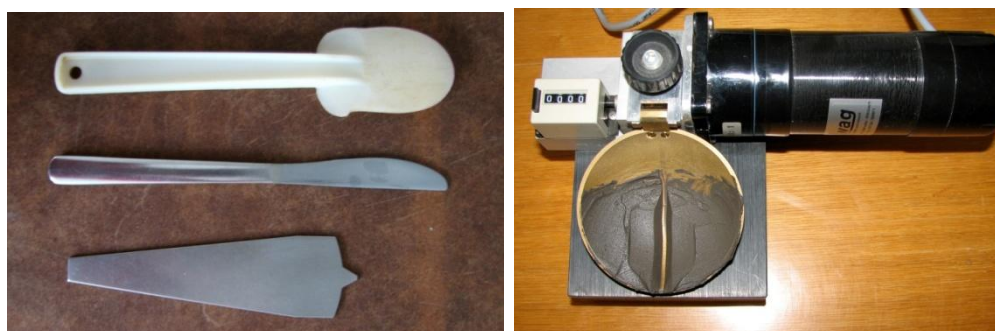

Fig. 1a (left) Spatula, knife and cutting knife (photo author, 2008) **Fig. 1b** (right) Casagrande device with a groove in the middle of the bowl before joining both cakes (foto autor, 2008)

3.1.2 ČSN CEN ISO/TS 17892/12: Geotechnical investigation and testing – Laboratory testing of soils – Part 12: Determination of consistency limits of soils.

The technical specification describes determination of the liquid limit using the cone test and determination of plasticity limits. With regard to the study of the liquid limit in this section only the procedure using the cone test will be explained for its determination.

For this test a cone was adopted with parameters - 60 g (weight)/ 60° (apex angle) and 80 g/ 30° and was proved that the acquired test results of the liquid limit using these shapes of cones are identical.

The test ought to run if possible on soil in its natural condition. In order to determine the liquid limit it is necessary to have about 200 g of soil passed through a sieve with a mesh size of 0.4 mm or the nearest. It is possible to determine the liquid limit also by a wet method (sedimentation up to pure water, which is time consuming and hardly realizable, see Annex 2, sections 6 – 15), however taking into consideration that the method was not a subject of investigation, it will not be described in more detail in this chapter. Provided that there is a large-grained material in soil it is necessary to be removed. The preference should be given rather to manual removal of grains than to wet sifting.

The prepared paste is properly mixed and if necessary we can add such quantity of distilled water the first penetration to achieve values to 7 mm for the cone of 60 g/ 60° and 15 mm for the cone of 30 g/ 80°.

A part of the mixed soil is moved with a flat knife to a clean and dry bowl whereas the tendency is not to mix the test sample with air. It is necessary to take off the excess soil with a yardstick by reason of creation of a smooth flat surface.

The penetration cone locked in a lifted position has to be lowered down so that it nearly meets the soil surface. The cone is in a correct position if and only if the cone tip will mark the soil surface while moving gently with the bowl.

Then the cone is released and left in the lowered position for 5 s +- 1s (Figs. 2a,b). Provided that the device is not equipped with an automatic releasing and locking device it is necessary to mind any jolt of the device not to happen while releasing.

Penetration by the cone (depth of cone sinking) is calculated as a difference between the initial and final positions of the cone shank and rounded to 0.1 mm.

Then the cone is pulled out and cleaned and a little of wet soil is added to the bowl so that no air bubble is created. The surface is leveled.

It is necessary to repeat the procedure till the difference between two following penetrations is lower than 0.5 mm for the cone of 80 g/ 30° and 0.4 mm for the cone of 60 g/ 60°. The average of two last penetrations has to be calculated.

From the penetration zone of the cone a sample (+-10 g) is taken, for which moisture is determined according to the CEN ISO/TS 17892-1 standard – Geotechnical investigation and testing – Laboratory testing of soils – Part 1: Determination of water content.

It is necessary to repeat the whole procedure at least three times (total 4 tests) using the identical test sample, but with a different water content. The quantity of water dried (or delivered) has to be such that the range of penetration values to be covered by four and more repeating tests.

As for the test results the relation of the water content (%) and the cone penetration is plotted in semilogarithmic scale with the water content on the horizontal axis and the cone penetration in logarithmic scale on the vertical axis. Then the best line substitution is depicted, i.e. the connecting line of the plotted points. From the diagram the water content has to be read that corresponds to 10 mm of the cone penetration while using the cone of 60 g/ 60° or the water content matching to 20 mm of the cone penetration while using the cone of 80 g/ 30°.

Fig. 2a (left) Cone test – cone sinking into paste **Fig.. 2b** (right) Penetrometer after sinking

3.2 Methodical differences in both standards

As of May 1, 2008 the ČSN 72 1014 standard – Laboratory determination of liquid limit of soils was cancelled. It was superseded by the new European standard ČSN CEN ISO/TS 17892-12 Geotechnical investigation and testing – Laboratory testing of soils – Part 12: Determination of consistency limits. Both standards describe the test method for determining the consistency limit of soil. The liquid limit w_L is determined using the Casagrande device (ČSN 72 1014) or Vasiljev cone (ČSN CEN ISO/TS 17892-12). The methodical procedures are different.

Moisture and plasticity affect in a decisive way mechanical properties of soils. If the soil has a slurry consistency, is liquid and has no solidity and thus is not able to transmit any load. On the contrary the same soil with diminutive water content can have a hard consistency; such soil has a high strength and is able to transmit relatively heavy loads. A specific cohesive soil has constant consistency limits. The difference between the liquid limit and the plastic limit so-called plasticity index I_P is constant, too.

Through the first method we determine the liquid limit when a sample of soil with a horizontal and smooth surface placed in the bowl of the device and divided by a standard knife into two parts which need 25 hits of the bowl to the base to close the gap between them in a length of 12.5+-0.5 mm namely at a rate of 2 hits per second. If we use the Vasiljev cone such water content matches to the liquid limit whereat the smooth metal cone with the apex angle of 30° and weight of 80 g (60 g/ 60°) placed on a smooth surface of the sample sinks into a depth of 10 mm during five seconds by self-weight.

According to the obsolete standard ČSN 72 1014 the test was realized using the Casagrande device especially in a one-point way. It means that the entire procedure was carried out only once and the test had one result. While according to the European standard ČSN CEN ISO/TS 17892-12, when the test is realized using the Vasiljev cone it is necessary to repeat the procedure four times always. It concerns thus the test being performed in a four-point way. It follows from this that the actual standard is more precise due to higher number of measurements. The final values are very similar indeed, however not fully the same. Therefore it is necessary to distinguish the methods. By the symbol w_L we denote usually the liquid limit from the Casagrande test, by the symbol $\overline{w_L}$ from the Vasiljev test.

An assessment of results is performed through the use of computer programs. One of them is the program "Classification analyses of soils" by Štěpánek V. (www.stepanek.cz). The program automatically assesses the liquid limit after entry of all required values. According to the obsolete standard it processed curves and summary sheet only. According to the new standard also reports to all description tests are elaborated.

4 COMPARISON OF MEASUREMENT RESULTS ACCORDING TO ČSN AND EUROPEAN STANDARDS

In order to determine the liquid limit 52 tests in total was made in two stages (tab.1). The first stage passed using the Vasiljev test according to the new European standard ČSN CEN ISO/TS 17892-12 under the name "Geotechnical investigation and testing – Laboratory testing of soils – Part 12: Determination of consistency limits". The second stage represented measurements of identical samples through the use of the method of the Casagrande bowl according to the older standard ČSN 72 1014 "Laboratory determination of liquid limit of soils", followed by the stage of correlation of results from both methods always with an identical sample in order to be possible to perform the comparison at all.

Comparing groups of results through the use of the Vasiljev and Casagrande methods a limit of gross error (4%) was conventionally determined between values of both methods according to experience from the course of the entire study. The limit is graphically illustrated below in diagrams (see Fig.3) with results of tests

(yellow line). It is recommended to repeat the tests with values over the mentioned limit. The full group of measurements involved 9.43 % inapplicable (with gross error over 4%) values.

Regression diagrams (see Fig. 4) show a dependence of the test results according to Casagrande on the results according to Vasiljev. The used regression allows analyzing the way in which values of one or more independent variables affect the value of one dependant variable. The linear regression being applied at the two methods of measurements was carried out using one of the most widely used least squares methods by alignment of the set of observations.

The value of reliability should utmost tend to the number 1, for it is the value representing the condition with the highest accuracy of the given value. For the complete group of the conducted tests the value is 0.9780 (see Tab. 2), which means the results are relatively very exact. Also the error of mean value 1.043 is low for the results (see Tab. 2).

A *statistical evaluation* was performed, whose parameters are presented in Tab. 3.

Mean value is a parameter of distribution of a random variable that is defined as weighted mean of the given distribution. The mean of the results difference was 2.549%. More transparently it is illustrated in Tab. 4 and in histograms of frequency (see Fig. 5, obr. 6, obr. 7).

Median is the value of the argument X with the highest absolute frequency, which means that approximately 50% values are higher and 50% lower than the value. There are not great deviations in both groups of measurements for the statistical value.

Standard deviation expresses, how the values differ from the mean value (mean values – Tab. 3).

Population variance represents so-called characteristics of variability (Tab. 3).

Kurtosis determines a relative kurtosis or flatness of distribution in comparison with normal distribution. During the calculation of kurtosis biquadrate is used. Kurtosis is negative, which means that the distribution is relatively flat.

Skewness denotes an asymmetry degree of the value distribution round the mean value. Positive skewness denotes a distribution with an asymmetric side that deviates towards more positive values. Negative skewness denotes a distribution with an asymmetric side that deviates towards more negative values. During calculation of skewness the third power is used. The measured results are skewed positively.

Minimum is the smallest measured value (Tab. 3).

Maximum is the highest measured value (Tab. 3).

Difference min – max is the difference between the lowest and the highest values. (Tab. 1, obr. 3 a tab. 4).

Sum is a sum of all measured values (Tab. 3).

Count is a total number of values (Tab. 3).

Tab. 1 Measured values (values with the difference higher than 4 % and with a recommendation to repeat both tests are illustrated by oblique font)

| Number	Sample	Casagrande	Vasiljev	Difference	Number	Sample	Casagrande	Vasiljev	Difference
1	23326	37,25	38,40	1,15	27	23327	40,14	42,8,	2,66
2	23303	32,65	33,80	1,15	28	23301	30,32	33,00	2,68
3	23304	35,73	36,90	1,17	29	23312	29,95	32,63	2,68
4	23309	32,72	33,90	1,18	30	23316	25,06	27,78	2,72
5	23339	35,11	36,30	1,19	31	23335	27,07	29,80	2,73
6	23305	33,18	34,37	1,19	32	23318	49,08	51,83	2,75
7	23311	32,8	34,02	1,22	33	23340	26,92	29,67	2,75
8	23313	37,82	39,06	1,24	34	23341	30,89	33,65	2,76
9	23319	24,57	25,98	1,41	35	23307	23,21	26,00	2,79
10	23306	25,05	26,50	1,45	36	23342	33,61	36,41	2,80
11	23320	26,80	28,29	1,49	37	23330	35,65	38,5	2,85
12	23322	29,11	30,65	1,54	38	23343	38,75	41,68	2,93
13	23317	49,56	51,2	1,64	39	23344	28,79	32,34	3,55
14	23324	36,12	37,85	1,73	40	23345	36,98	40,53	3,55
15	23323	32,49	34,24	1,75	41	23314	31,73	35,30	3,57
16	23321	35,66	37,44	1,78	42	23346	46,52	50,13	3,61
17	23331	26,29	28,10	1,81	43	23328	33,02	36,70	3,68
18	23332	29,11	30,99	1,88	44	23347	47,31	51,07	3,76
19	23334	41,18	43,06	1,88	45	23348	42,18	46,00	3,82
20	23315	32,64	34,60	1,96	46	23329	28,16	32,00	3,84
21	23336	39,01	41,02	2,01	47	23349	39,52	43,43	3,91
22	23325	46,72	48,80	2,08	48	23350	27,17	31,17	*4,00*
23	23337	30,62	32,79	2,17	49	23300	27,97	32,00	*4,03*
24	23338	44,01	46,59	2,58	50	23351	28,19	32,25	*4,06*
25	23308	29,45	32,06	2,61	51	23352	36,59	41,37	*4,78*
26	23310	21,49	24,11	2,62	52	23333	30,09	35,00	*4,91*
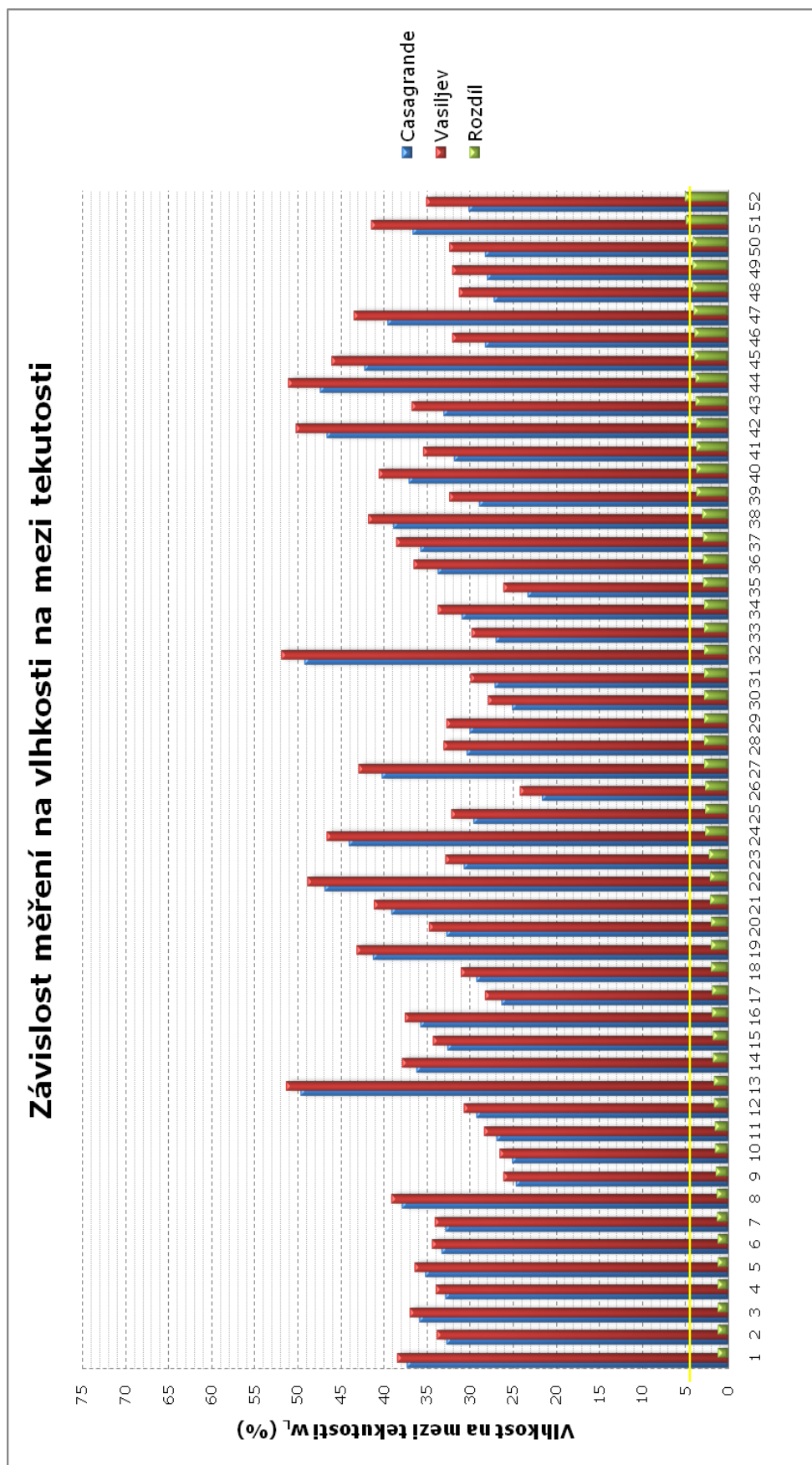
Fig. 3 Diagram of liquid limit measurement according to the Vasiljev cone (red column) and the Casagrande bowl – individual measurements are arranged according to the size of the values difference

Vasiljev cone (red column) and Casagrande bowl (blue column) with presentation of their differences (green column) for liquid limit measurement. By the yellow line the limit of values with difference of 4 % (conventional limit) over which the tests repeat is recommended, is illustrated.

Tab. 2 Parameters of regression of measurement values of the Casagrande and Vasiljev methods

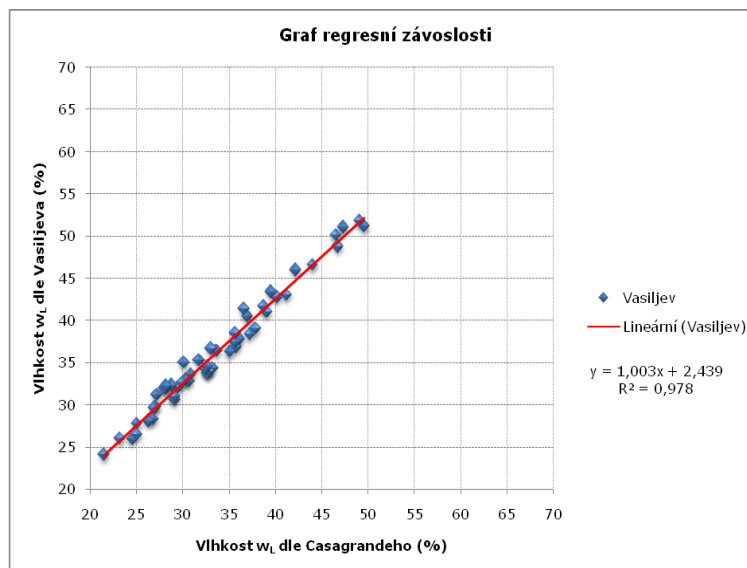| Regression statistics	
Multiple R	0,988957747
Value of reliability R	0,978037426
Set value of reliability R	0,977598175
Error of mean value	1,043435149
Observations	52

Fig. 4 Regression of measurement values of the Casagrande and Vasiljev methods
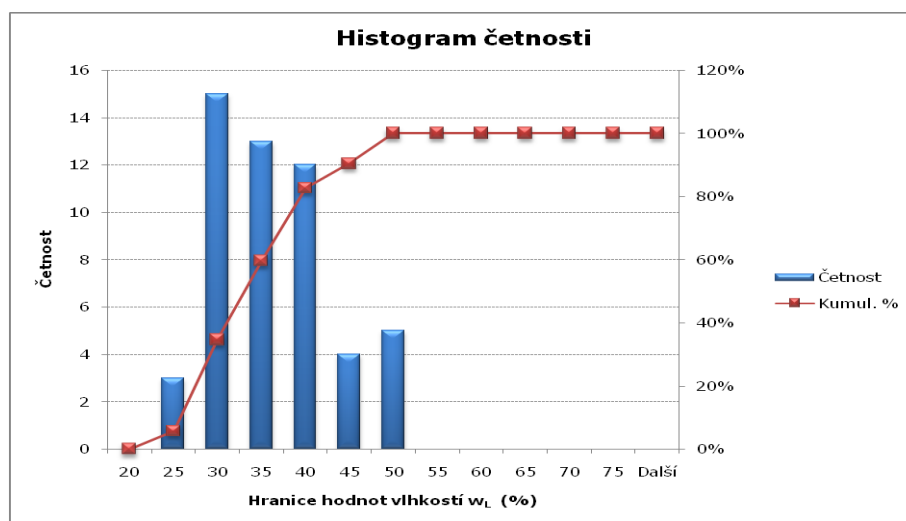

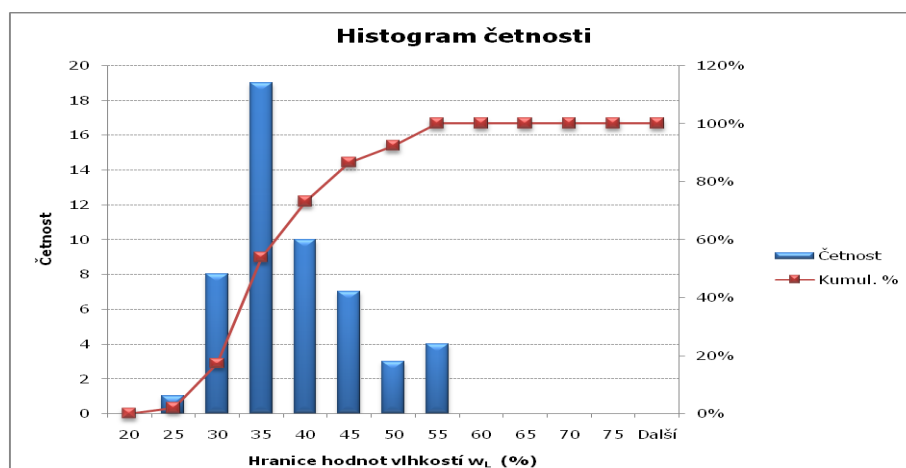**Fig. 5** Histogram of frequency of liquid limit according to Casagrande

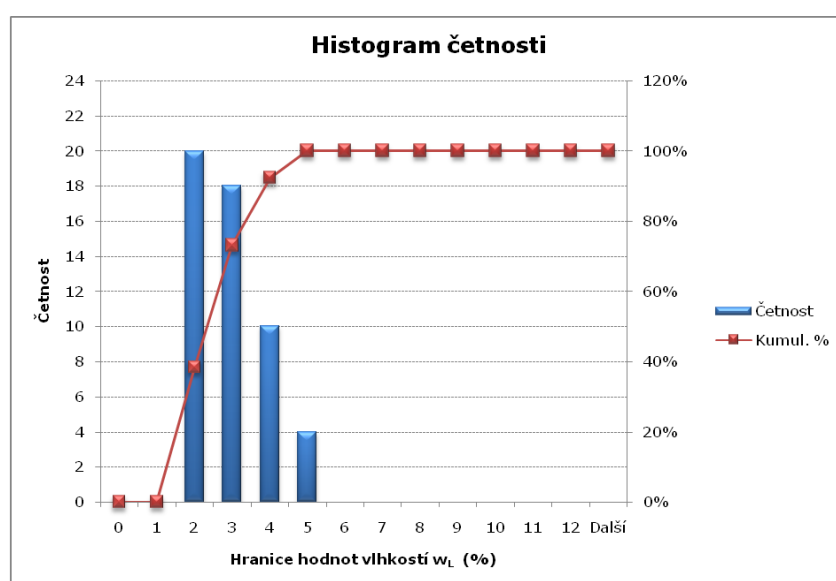**Fig. 6** Histogram of frequency of liquid limit according to Vasiljev

Fig. 7 Histogram of frequency of difference values of liquid limit for tests according to Casagrande and Vasiljev

Tab. 3 Table with a presentation of values of geostatic parameters of the measurement group with assistance of an experienced laboratory assistant (data analysis)

Casagrande		*Vasiljev*		*Difference*	
Mean value	33,6925	Mean value	36,23192308	Mean value	2,539423077
Error of mean value	0,953262473	Error of mean value	0,966767602	Error of mean value	0,143300729
Median	32,685	Median	34,485	Median	2,64
Course deviation	6,874073449	Course deviation	6,971460319	Course deviation	1,033356256
Population variance	47,25288578	Population variance	48,60125897	Population variance	1,067825151
Kurtosis	-0,18959265	Kurtosis	-0,1593365	Kurtosis	-0,78527328
Skewness	0,617485563	Skewness	0,638333452	Skewness	0,385714018
Difference max-min	28,07	Difference max-min	27,72	Difference max-min	3,76
Minimum	21,49	Minimum	24,11	Minimum	1,15
Maximum	49,56	Maximum	51,83	Maximum	4,91
Sum	1752,01	Sum	1884,06	Sum	132,05
Count	52	Count	52	Count	52

Tab. 4 Table with a presentation of basic categories of measurements according to accuracy of moisture measurements at the liquid limit

	measured values	
	Number of values	*Mean in %*
Very exact measurements (to 1%)	0	-
Exact measurements (1-3%)	47	2,346
Inexact measurements (over 4%)	5	4,356
All values	52	2,549

4.1 Differences and errors in standards

Both tests are encumbered by errors. It is known that the test results are affected by personal approach of the laboratory assistant which implicates a difference occurrence between individual measured test results. Consistency limits are affected by oxidation and other changes of the test sample in consequence of e.g. a long-lasting storage or a rough handling with the sample. It pertains especially to sensitive clays, clay with a content of sulphides and organic soils. Therefore the determination of consistency limits for such clays has to run immediately after puggding (ČSN CEN ISO/TS 17892-12).

The liquid limit test results of both methods are affected also amount of time required to perform the test and initial water content of soil. While testing by means of the Vasiljev cone errors can occur caused by improper pugging of the paste namely prior to let the sample aged or before the test itself.

4.1.1 Errors during the cone test according to Vasiljev

For the test it is necessary to prepare 200 g of soil. The test results are more considerably affected by surface roughness of the cone, less considerably then by a deviation of the cone angle or bluntness of the cone apex. To avoid affecting the test for these reasons it is necessary to check the device carefully at least once a year. It is obvious from both standards that during years the cone weight changed. The old standard ČSN 72 1014 states that the total cone weight even with equilibrium equipment has to match to 76 g ± 0,2 g. In the new standard ČSN CEN ISO/TS 17892-12 is then stated that the cone weight depends on its angle. The cone weight has to be 60 g for apex angle 60 °, or 80 g for apex angle 30° (used during measurements). The test is affected also by observance of correct parameters of further aids (e.g. scale, set of sieves, mixing vessel etc.), whose parameters are given in the standard ČSN CEN ISO/TS 17892-12. For proper realization of the test it is necessary to comply with all mentioned conditions of the test and measuring device has to comply with the standard parameters. The cone test is less affected by an error caused by human factor as it is in case of the test according to Casagrande, for it is more mechanized and performed at least four times (four-point method) and these four results are averaged. The laboratory assistant only reads the penetration on the penetrometer.

4.1.2 Errors during the test according to Casagrande

The Casagrande method is an alternative method for determining the liquid limit of soil. Both the Casagrande device and methodology of the test passed through many small but considerable modifications since the procedure was first presented by Casagrande in the year 1932. In former times the Casagrande device had a arm that turned at a rate of 2 revolutions per second which caused the bowl with the cut cake of soil was put in motion. Later the device was automated so that the arm was replaced with a motor. Another difference is a possibility of various surface roughness of the Casagrande bowl given by duration of its utilization or by different roughness as from its production.

For the test it is necessary 50 g of soil. As regards the very accomplishment of the test the highest inaccuracies occur during the test due to an incorrect estimation of the length of joining of both cakes of soil. It is necessary to determine precisely during which hit the cakes join to the required length of 12.5 mm (+- 0.5 mm). Not always the situation is fully obvious and the personal approach of the laboratory assistant here plays a role. Each laboratory assistant can see the precise joining both cakes at different number of hits. Another aspect is a long-lasting practice. In former times when the old standard ČSN 72 1014 applied it was therefore required the test to be performed in a laboratory by one person only. The geologists that then used the results for further processing got accustomed to the approach of just one laboratory assistant and could better cooperate with him. During the test it is necessary to pay an increased attention to a right shape of the cutting knife and adjusting the device, especially the height of the bowl travel.

Differences in measured values are then caused especially by the mentioned errors. Considering that it concerns exact measurements even a small deviation may cause a greater difference in results.

4.2 Conventions of laboratory

Carrying out the tests exactly according to the European standard ČSN CEN ISO/TS 17892-12 is very difficult and time-consuming. It concerns especially the preparation of the sample according to the standard.

There is stated that "it is necessary to have about 200 g of natural soil passed through a sieve with a mesh size of 0.4 mm or the nearest", while the natural soil is a sample taken e.g. from a borehole etc. and delivered to the lab. It has its natural water content and mostly a firm consistency, therefore it is nearly impossible to pass it through a sieve. Further there is set forth that "the soil has to settle down for a reasonable period of time and then clean water has to be poured off." This suspension has to be partially dried in the air or in a drying chamber at the temperature not exceeding 50 °C or if appropriate by filtration unless a consistent paste occurs. A local overdrying of the surface or edges has to be avoided by repeated mixing. The consistency of the paste has to match the penetration of 7 mm when using the cone of 60 g / 60° or 15 mm for the cone of 80 g / 30°." However, in fact the procedure could take a month and more which is unacceptable.

The laboratories follow the standard, but they perform the tests according to their conventions. These are given in a written document and in the final report there is stated that the test is carried out in conformity with the methodical procedure according to ČSN CEN ISO/TS 17892-12 and lab conventions.

4.3 Effect of petrographic composition of soils to the liquid limit

A further aspect being important for the tests is a *mineral composition of soils*, especially then clay minerals. These belong to the most widespread minerals in the rock system of the Earth's crust and are a substantial part of the soil horizon.

Clay is a rock containing at least 50 percentages by weight of particles less than 2 μm. It is a mixed natural material primarily compounded from soft granular materials that is commonly plastic for reasonable water content and sets up after drying or baking. A part of clay are especially sheet silicates, i.e. silicates with a sandwich type structure, but besides them clays may contain also another minerals and organic matter that can but need not affect their plasticity or a drying or baking by hardening. These minerals involve for instance crystalic or non-crystalic modifications of SiO_2, mineral groups of allophanes, feldspars, zeolites, carbonates or oxids and ferrum or aluminium hydroxides.

While specifying *"clay minerals"* certain problems occur. From the general mineralogy point of view we may not lean against the classification categories such as particles size or degree of plasticity, because these are not involved there (and may not be either). To identify the concept "clay minerals" with minerals contained in clays is also unacceptable namely not only because in clays a whole series of minerals belonging to various groups of valid mineralogical system may be involved, but also because it opposes to up to now understanding of the concept "clay minerals" by the expert community. Despite these problems the joined AIPEA and CMS Nomenclature Commitees ((Guggenheim, Martin, 1995) have agreed on the minerals present in clays may be divided into two following categories:

1. *Clay minerals*

Here belong not only all sheet silicates, but also further minerals such as minerals of the group of alophanes or some hydroxides, oxy – hydroxides and oxids that add clays plasticity and that are set up by drying or baking. Unlike sheet silicates they are only minority components of clays.

2. *Accompanying minerals*

These are then such minerals that may be indeed contained in clays, but they do not rank among the above mentioned clay minerals (Weiss, et al, 2005).

Cohesive soils are mixtures of clay, dust and often even sandy grains. In nature they can contain bound and free water. The quantity of water increases in soil with a portion of a clay mineral and exchangeable cations. The larger the specific surface of soil, the more and the more active clay minerals and exchangeable cations the soil contains, the greater its capability to bind and hold water (the greater also its plasticity index I_P).

Except for the consistency limits also a series of further related characteristics exists. Here are the most important (Weiss, et al, 2005).

1. *Absorbing capacity*, i.e. quantity and promptness of absorption of water by dried, crushed soil. (Determined by Enslin).

2. *Clay activity* is expressed as a ratio of plasticity index I_P (%) and percentage proportion of clay grain of d < 0,002 mm to grain size distribution of soil. Clays with identical mineralogy composition, origin and geological past have identical activity. (Determined by Skempton).

3. *Maximum molecular water content* w_{max} is a quantity of water that may not be removed from soil even by centrifugal force equal to 70,000 multiple of gravitation (Determined by Lebedjev).

5 CONCLUSION

The subject of the study is the liquid limit that is an empirically determined state at which a transition from a softly plastic to liquid (pasty) state occurs, therefore after its achieving soil starts to behave as a liquid substance.

The liquid limit measurement is principal especially for finding consistency states playing a decisive role for determining the key standard characteristics of soils representing important geotechnical parameters of fine-grained soils (as categories of foundation soil according to the standard ČSN 73 1001 Foundation soil under spread footing) for investigations of the so-called first geotechnical category. It is an input parameter for calculation of the consistency and plasticity indices of soils being interconnected with the above mentioned.

The study was realized by two methodologies of liquid limit measurements by the Casagrande bowls and cone tests by Vasiljev. The finding was not based only on comparison of two differing methods for one parameter, but also on discovery of an important continuity of the older Czech standard (ČSN 72 1014 Laboratory determination of liquid limit of soils) and the newly implemented European standard (ČSN CEN ISO/TS 17892/12: Geotechnical investigation and testing – Laboratory testing of soils – Part 12: Determination of consistency limits. Further meaning is bound to utilization of a large file of in-past-realized engineering geological investigations with determination of the parameter and on a need to use them at present in newly realized investigations according to the found correlation state. Archive works are available through the Geofond of the Czech Republic.

The study was assessed based on 52 realized laboratory tests, whereas each test was carried out on the same sample of foundation soil. Initial procedure insisted in cutting by a knife, drying in a drying chamber, sorting using electric mill, additional watering by distilled water and mixing. In conclusion before realization of the tests the sample set up for 24 hours for the purpose of even distribution of moisture.

Subsequently the Casagrande bowl test and the Vasiljev cone test were realized. It is important to perceive the cone test is according to the standard carried out four times on an identical sample, while the Casagrande method only once. Another significant differences are obvious both in using of devices and performance of the test itself.

The sample values ranged from 21.49 to 49.56 % according to Casagrande and in the conical test they ranged from 24.11 to 51.07 %. The difference of the results for identical samples reached values from 1.15 to 4.19 %. Mean difference coefficient between the methods is 2.549 %.

It is possible to use the mean difference coefficients in future as correlation coefficients, whereas it would be necessary to precise their application by a larger file of comparing tests. However, their finding is important, because it facilitates the application of the archive values according to Casagrande and at present realized tests by Vasiljev in one engineering geological investigation within the same locality.

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RESUMÉ

V podmínkách Evropské unie při implementaci nové legislativy v geotechnice vyvstala problematika kompatibility metod pro měření vlhkosti na mezi tekutosti stanovované podle Českých státních norem a přijímaných evropských norem. Existující ČSN stanovovala vlhkost na mezi tekutosti pomocí tzv. Casagrandeho misek, přičemž nová evropská norma pomocí kuželové zkoušky. Studovaná kompatibilita má řadu velmi

důležitých praktických konsekvencí. Jedná se především o desetitisíce provedených průzkumů realizovaných v celé České republice podle předchozí metodiky, které bychom mohli využívat při budoucích inženýrskogeologických průzkumech v rámci etapy archivního studia dosavadní prozkoumanosti. Je však nutno při studiu parametru vlhkosti na mezi tekutosti znát korelační vztah těchto dvou parametrů stanovených dvěmi rozdílnými metodami.

Vlhkost na mezi tekutosti je stav empiricky stanovený, při kterém nastává přechod z měkce plastického do tekutého (kašovitého) stavu, tudíž po jeho dosažení se zemina začíná chovat jako tekutá látka.

Pomocí Casagrandeho misek získáme vlhkost na mezi tekutosti tehdy, když se koláček zeminy, s vodorovným a uhlazeným povrchem, umístěný v misce přístroje a rozdělený normovým nožem na dvě části, slije po 25 úderech misky o podložku v délce 12,5 ± 0,5 mm, a to při rychlosti dvou úderů za sekundu.

U kuželové zkoušky je metodika založena na tom, že mezí tekutosti je ta vlhkost, při níž se hladký kovový kužel se středovým úhlem 30° a s hmotností 80 g, položený na uhlazený povrch vzorku, zaboří vlastní tíhou do hloubky 20 mm během 5 sekund.

Podrobný postup předepisuje norma „ČSN CEN ISO/TS 17892/12: Geotechnický průzkum a zkoušení – laboratorní zkoušky zemin – Část 12: Stanovení konzistenčních mezí". Touto normou se nahrazuje „ČSN 72 1014 Laboratorní stanovení meze tekutosti zemin".

Vlhkost na mezi tekutosti je zásadní zejména pro zjišťovaní konzistenčních stavů, které mají rozhodující význam pro stanovení směrných normových charakteristik zemin, které představují důležité geotechnické parametry jemnozrnných zemin (jako tříd základové půdy dle normy ČSN 73 1001 Základová půda pod plošnými základy) pro průzkumy tzv. první geotechnické kategorie. Je vstupním parametrem pro výpočet Indexu konzistence a Indexu plasticity, které s výše uvedeným úzce souvisí.

Práce byla realizována na základě 52 laboratorních zkoušek, přičemž každá zkouška byla provedena na tomtéž vzorku základové půdy.

Rozpětí hodnot u zjištěných vzorků se pohybovalo od 21,49 do 49,56 % dle Casagrandeho a u kuželové zkoušky se pohybovalo v hodnotách od 24,11 do 51,07 %. Rozdíl výsledků u identických vzorků dosahoval hodnot od 1,15 do 4,19 %. Průměrný rozdílový koeficient mezi metodami je 2,549 %. Průměrné rozdílové koeficienty je možno v budoucnu použít jako korelační součinitele, přičemž jejich použití by bylo třeba upřesnit ještě větším souborem porovnávacích zkoušek. Nicméně, jejich zjištění je důležité, protože usnadní použití archivních hodnot dle Casagrandeho a v současnosti realizovaných zkoušek dle Vasiljeva u jednoho inženýrskogeologického průzkumu v rámci stejné lokality.