



PRACTICAL AID TO IDENTIFY AND EVALUATE PLASTICITY, SWELLING AND COLLAPSIBILITY OF THE SOIL ENCOUNTERED IN BADRAH, SHATRA AND NASSIRYA CITIES

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Abstract: The plasticity properties of soil are sufficiently variable to offer a simple but practical aid to identification. This can be done by using their Atterberg limit values as parameters for an identification chart. This paper attempts to identify and evaluate major soil types encountered within the areas of Badrah, Shatra and Nassirya Cities based on a large number of laboratory test results conducted to determine its index and physical properties. A new line on plasticity chart was established and corresponding to the mean of more than three hundred plasticity tests. The swelling characteristics of investigated soil were evaluated using the classification system developed by Savage (2007). Savage original chart was modified and new chart established at which the estimated gross plasticity index, using an advanced statistical analysis software package named "Number Cruncher Statistical System (NCSS)", with assistance of resulting functional relation and LL and PL can be used to assess the suspect soil to swell quickly with no need to conducted sieve analysis test. New chart developed to identify the collapsibility of the investigated soil according to Holtz and Hilf method. The LL and w were used to evaluate the collapsibility of soil from the established limiting curves.

Keywords: Atterberg limits, physical properties, collapsibility, swelling, regression analysis, NCSS

مساعدة عملية لتحديد وتقييم اللدونة والانتفاخ والانهيارية للتربة في مدن بكرة والشطرة والناصرية

الخلاصة: إن الخصائص اللدنة للتربة متغيرة بما فيه الكفاية لتقديم مساعدات بسيطة ولكنها عملية لتميز التربة. ويمكن القيام بذلك عن طريق استخدام محدود اتربرغ كمؤشرات لمخطط تصنيف التربة. يهدف البحث الحالي إلى تحديد وتقييم أنواع التربة الرئيسية ضمن مدن بكرة والشطرة والناصرية بالاعتماد على عدد كبير من نتائج الاختبارات المعملية التي أجريت لتحديد مؤشر والخصائص الفيزيائية للتربة. لقد تم إنشاء خط جديد ضمن مرتسم اللدونة بناءً على نتائج أكثر من ثلاثمائة اختبار لللدونة. تم تقييم خصائص الانتفاخ في التربة باستخدام نظام التصنيف الذي وضعه سيفيج عام (2007). تم تعديل المخطط الأصلي لسيفيج وإنشاء مخطط جديد باستخدام القيم المخمئة لمؤشر اللدونة الاجمالي وذلك باستخدام برنامج التحليل الإحصائي المتقدم المسمى (NCSS) ومساعدة المعادلة التي تم التوصل إليها من البرنامج الإحصائي ونتائج حدي السيولة واللدونة بحيث أصبح بالإمكان تقييم قابلية التربة للانتفاخ بسرعة دون الحاجة لإجراء اختبار التحليل المنخلي. تم تطوير مرتسم جديد للتعرف على قابلية الانهيار للتربة استناداً إلى طريقة (Holtz and Hilf). تم استخدام حد السيولة ومحتوى الماء الطبيعي للتربة في تقييم انهيارية التربة من منحنيات الحد المعمول بها.

1. Introduction

Index properties have been in wide use in the study of engineering soils for preliminary soil classification and in the characterization of different groups of soils having distinct

engineering characteristics, more generally, in the formulation of local engineering soil classifications and in the interpretation of engineering test results [1].

This paper attempts to identify and evaluate major soil types encountered within the area of Badrah, Shatra and Nassirya Cities (BSN). An evaluation and estimation of some physical and engineering properties of soil was carried out based on a large number of laboratory test results conducted to determine its index and physical properties.

Nonlinear and simple linear regression analysis was carried out using an advanced statistical analysis software package named Number Cruncher Statistical System (NCSS). This analysis aims to find an appropriate mathematical model that expresses the relationship between a dependent variable (plasticity index PI, gross plasticity index Pg, and dry unit weight γ_d) and a single independent variable (liquid limit LL, plasticity ratio R, and the ratio of liquid limit LL to natural water content w) and estimating the values of its parameters.

The swelling characteristics of soil were evaluated using the classification system developed by Savage [2]. Identification for the collapsibility of the investigated soil was achieved according to Holtz and Hilf method [3].

2. Evaluation of Plasticity and Developed BSN-Line

It has been observed that many properties of cohesive soil, such as their dry strength, compressibility, reaction to the shaking test, and consistency near the plastic limit, can be correlated with the Atterberg limits by means of the plasticity chart. Casagrande proved that not only the difference between liquid and plastic limits is suitable for the identification and classification of soil, but also their location on the (LL, PI) coordinates system. Furthermore, Casagrande pointed out the possibility of arriving at conclusions there on the strength of the soil, [4].

Experience has shown that the points which represent different samples from the same soil stratum define a straight line that is roughly parallel to line A. As the LL of soils represented by such a line increases, the plasticity and the compressibility of the soils also increase, [5]. Thus, determination of the distribution of investigated soil on the plasticity chart is necessary. To achieve this purpose, values of LL, PL, and PI of three hundred and thirty eight samples were plotted on Fig. 1. All tests were conducted in the same laboratory on samples taken from different locations of Badrah, Shatra and Nassirya cities.

The close correlation of the points determined on the basis of simple linear regression analysis using an advanced statistical analysis software package named "Number Cruncher Statistical System (NCSS)". The constants in linear relationship were calculated by utilizing curve fitting approach. BSN-Line (Badrah, Shatra and Nassirya) is the name used to describe the line obtained from this analysis and corresponds to (338) plasticity tests on Badra, Shatra and Nassirya cohesive soil. Equation (1) shows the resulting equation (see Fig. 2).

$$PI = 0.7863 (LL - 15.31) \quad (1)$$

Examination of Fig. 2 reveals that there is close correlation of the points under investigation, which represents by a new line named (BSN-Line). This correlation is characterized by the correlation coefficient of (0.9369) which reflects a high functional relation. As a result, the plasticity index of soil within the investigated area can be directly

obtained with sufficient accuracy from (1) or from graphical construction shown in Fig. 2. BSN-Line runs above A-Line on the Casagrande chart by different in plasticity index ranged from (3.4) to (5.9) percent, thus, this line is approximately parallel to A-Line.

The dry strength of inorganic soils represented by points on lines located above A-Line increases from medium for samples with LL below 30 to very high for samples with LL of 100. On the other hand, if the line representative of inorganic samples from a given stratum is located at a considerable distance below A-Line, the dry strength of samples with a liquid limit less than 50 is very low, and that of samples with a liquid limit close to 100 is only medium, [5]. In accordance with these relationships, the dry strength of investigated soil from different localities but with equal LL increases in a general way with increasing PI.

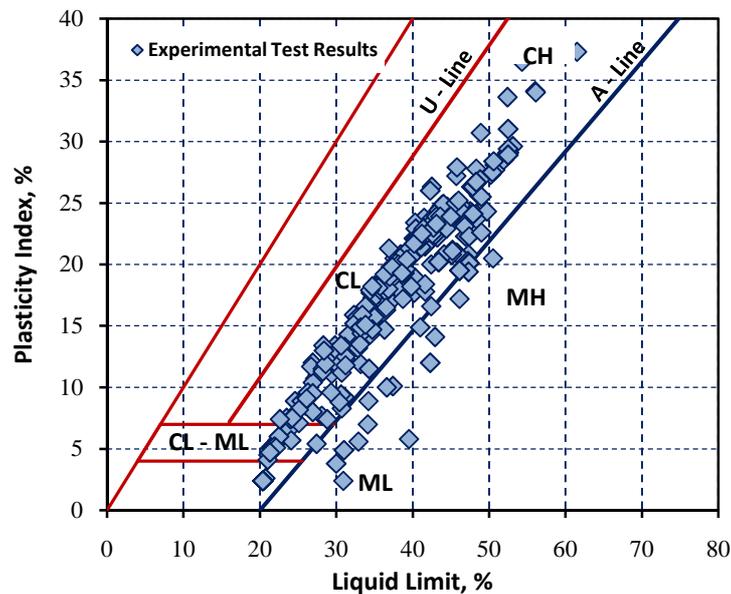


Figure 1. PI Distribution for investigated soil

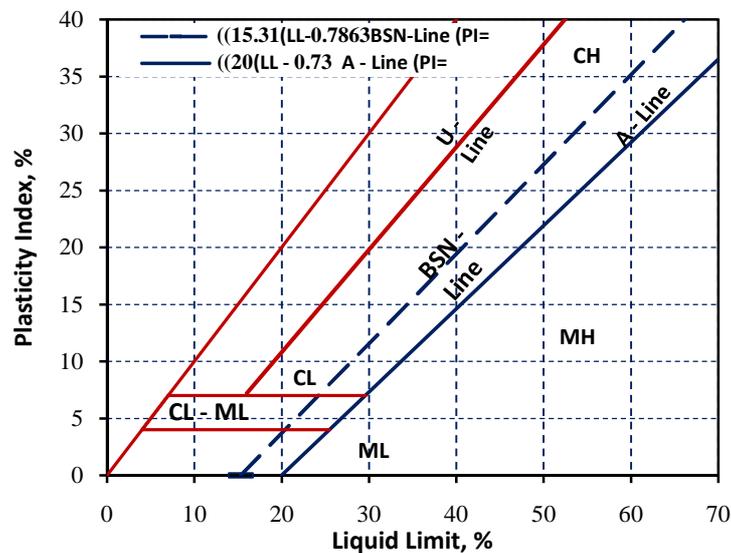


Figure 2. BSN-Line on the plasticity chart

3. Evaluation of Swelling Potential

An evaluation to swelling potential of investigated soil was carried out based on the Atterberg limits test result used in the previous analysis. The classification system developed by Savage [2] was adopted to achieve the above mentioned purpose. Van der Merwe [6] investigated the potential of clays to swell and drew up a chart of gross plasticity index (P_g) versus gross clay fraction (P_{002g}) in which zones of swell potential were defined ranging from low – medium – high –very high by a series of straight lines. Savage [2] established a mathematical derivation of lines representing swell potential by a factor K, certain values of which define the swell zones approximating those of Vander Merwe [6]. The mathematical evaluation of K which relates gross plasticity index (P_g) and gross clay content (P_{002g}) is given by:

$$(P_{002} - 0.73K)(P_g - 0.16P_{002}K^{0.4}) - K = 0 \quad (2)$$

Where

$P_g = PI * P_{425}$ and termed the gross plasticity index for the total soil.

P_{425} is the percent of soil fraction with diameter 0.425 mm

P_{002} is clay fraction = $6.25 P_g * R^{-2.13}$

$R = LL/PL$ and termed the plasticity ratio

Swell potential is defined by K, when ($K \leq 16$ low swells potential, $16 < K \leq 27$ medium swell potential, $27 < K \leq 37$ high swell potential, and $37 < K$ very high swell potential). Fig. 3 shows the K lines superimposed on the original Van der Merwe zones. Savage considers this should be quite acceptable [2].

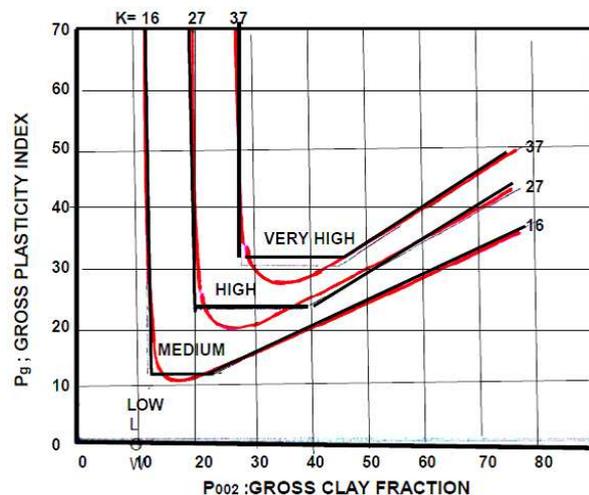


Figure 3. The Van der Merwezoning in terms of mathematical formulation

Savage [2] reformulated (2) to eliminate P_{002} by substitution from ($P_{002} = 6.25 P_g * R^{-2.13}$).

Thus:

$$P_g (1 - K^{0.4} * R^{-2.13})(6.25 P_g R^{-2.13} - 0.73K) - K = 0 \quad (3)$$

As this formula is rather extended for rapid calculation Fig.4 prepared which enables the swell potential of a soil to be estimated when the value of the gross plasticity index (P_g) and the plasticity ratio ($R = LL/PL$) is known. An additional value for $K (=57)$ had been added in order to divide very high swell potential and extremely high potential.

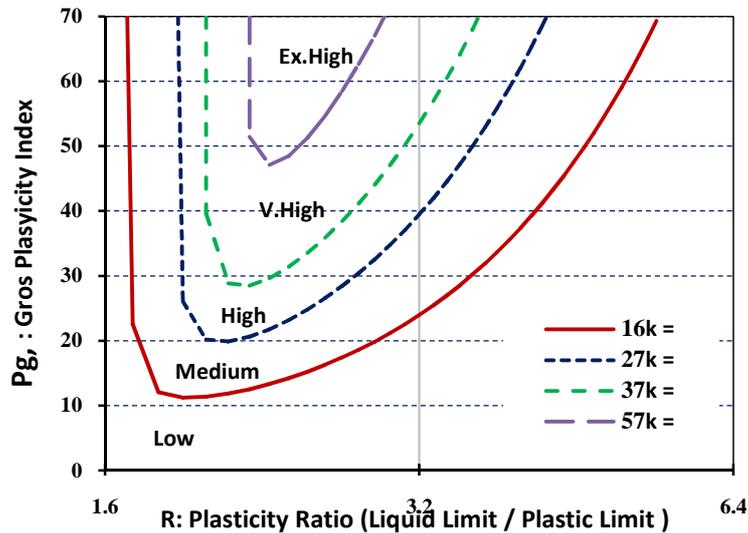


Figure 4. Swelling potential of soil from gross plasticity index and plasticity ratio (after Savage 2007)

Accordingly, to evaluate the swelling potential of investigated soil the plasticity ratio R and the gross plasticity index P_g were calculated and used to enable a suspect soil to be assessed quickly by the use of the Savage chart as shown in Fig.5. An examination to Fig. 5 reveals that the swelling potential of about seventy percent of investigated soil can be classified as low to medium, while about thirty percent of this soil may undergo high swell under saturation condition. It should be noted that low and medium swelling soils may be accepted for compaction but soils approaching the high zone should be considered suspect. Clay soils which fall within the high swell range or higher should not be compacted for high density, [2].

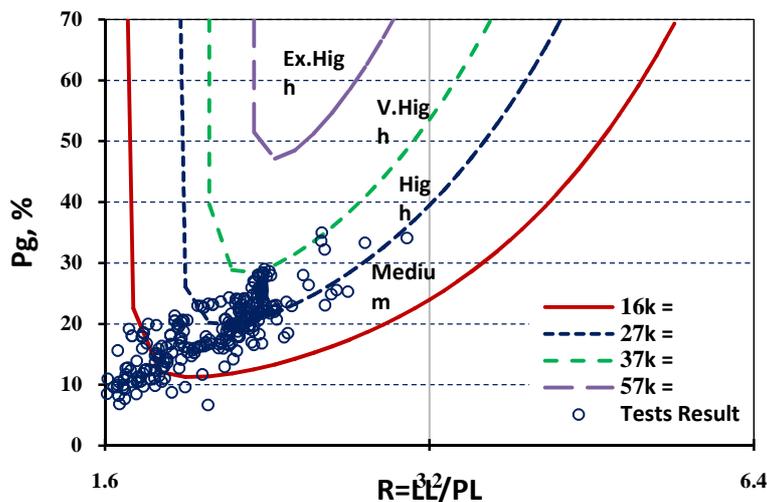


Figure 5. Swelling potential of investigated soil from gross plasticity index and plasticity ratio

To find an appropriate mathematical model that expresses the relationship between a dependent variable "gross plasticity index Pg" and a single independent variable "plasticity ratio R" and estimating the values of its parameters, simple regression analysis was carried out using (NCSS) software.

First plasticity ratio R and the gross plasticity index Pg were calculated, and then simple linear model used in regression analysis using the database compiled in this paper as shown in Fig. 6. Equation (4) represents the resulting functional relation with value of correlation coefficient of 0.9173.

The gross plasticity index of the investigated soil can be successfully estimated from the plasticity ratio using (4) with no need to conduct sieve analysis test. Furthermore, the estimated gross plasticity index with assistance of LL and PL can be used to assess the suspect soil to swell quickly by using the modified Savage chart at which resulting functional relation (4) is duplicated on the same chart as shown in Fig. 6.

$$Pg = 18.99 R - 19.47 \tag{4}$$

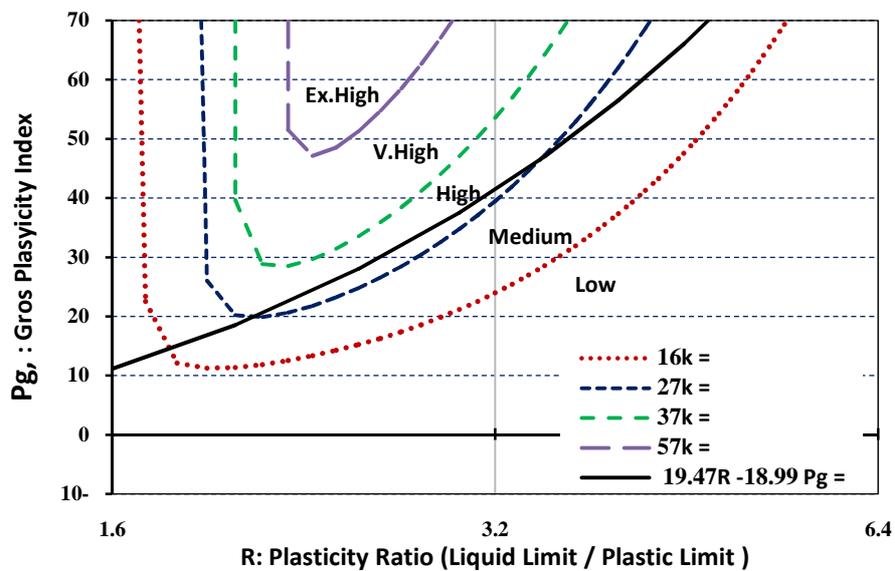


Figure 6. Developed chart to assess suspect soil to swell from soil plasticity (modified after Savage, 2007)

4. Evaluation of Collapsibility of Soil

Several investigations have proposed various methods for evaluating the physical parameters of collapsing soil for identification. According to Holtz and Hilf [3], soil that has a void ratio large enough to allow its moisture content to exceed its LL upon saturation is susceptible to collapse, [7]; [8], so for collapse:

$$w \text{ (saturation)} \geq LL \tag{5}$$

However, for saturated soils:

$$e_o = w G_s \tag{6}$$

combining (5) and (6) for collapsing soil yield:

$$e_o \geq LL \cdot G_s \tag{7}$$

The natural dry unit weight required for its collapse is

$$\gamma_d \geq (\gamma_w \cdot G_s) / (1 + e_o) = (\gamma_w \cdot G_s) / (1 + LL \cdot G_s) \tag{8}$$

For the whole investigation, based on the result of specific gravity test for more than 450 tests, G_s found to be ranged from 2.6 to 2.8 with an average value of 2.75. Assuming unit weight of water equal to 10 kN/m^3 and by substituting the value of specific gravity in (8), the limiting values of dry unit weight for various LL may now be calculated as shown below:

$$\gamma_d \geq 27.5 / (1 + 2.75 LL) \tag{9}$$

Equation (9) used to calculate the limiting values of dry unit weight for various liquid limits, as shown in Fig. 7. The distribution of values of liquid limit and dry unit weight for the investigated soil with respect to the limiting values of dry unit weight is shown in Fig. 7. Soils with an in-situ dry density and LL to the left of two lines should be investigated further for their collapse potential. The lower curve is for soils with a specific gravity of 2.6 and the upper curve is for G_s equal to 2.8. It can be noted that more than 95% of the investigated soil fall above limiting curve. This means that this soil is not a collapsible soil.

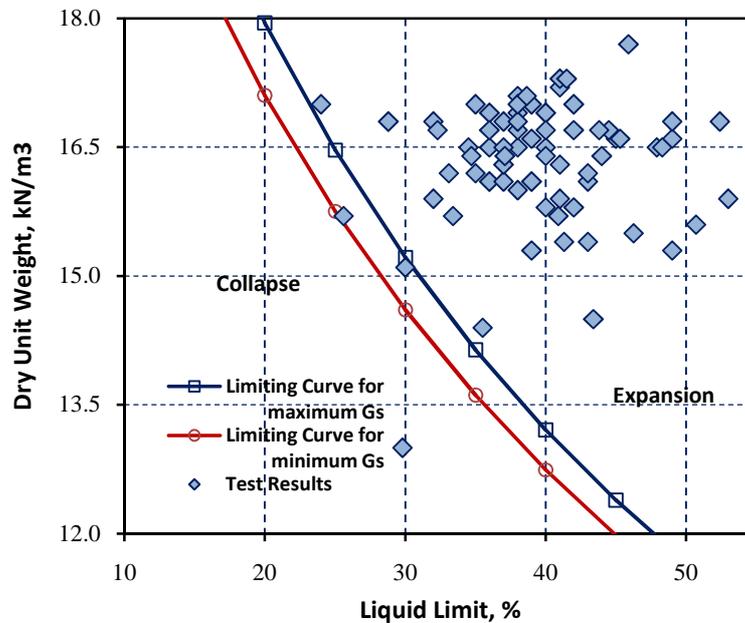


Figure7.Collapsibility based on dry unit weight and liquid limit

To find an appropriate mathematical model that expresses the relationship between a dependent variable "dry unit weight" and a independent variable "liquid limit/natural water content" and estimating the values of its parameters, nonlinear regression analysis was carried out using (NCSS) software. First liquid limit/natural water content and the dry unit weight were calculated, and then curve fitting with nonlinear model named (Linear-Linear) shown below used in regression analysis using the database compiled in this paper as shown in Fig. 8. Equation (10) represents the general form of adopted model with their common equation and parameter identities. Equation (11) shows the resulting functional relation with value of correlation coefficient of 0.6423.

$$y=A + B x + C(x-D) \sin (x-D)(10)$$

Where Common Equation : $y = a_1 + b_1 x, x < J$ and $y = a_2 + b_2 x, x > J$; while Parameter Identities : $A=(a_1+a_2)/2$, $B=(b_1+b_2)/2$, $a_1=A+DC$, $b_1=B-C$, $J=D$, $C=(b_2-b_1)/2$, $a_2=A - DC$, $b_2=B+C$

$$\gamma_d = 12.41 + 2.95 LL/w + (LL/w - 1.26) (-2.75 \sin ((LL/w) - 1.26)) \quad (11)$$

Equation (11) is graphically illustrated on Fig. 8 for more rapid determination of dry unit weight of the soil. It can be noted that the dry unit weight can be successfully estimated from the liquid limit and water content using (11). On the other hand, with assistance of liquid limit and water content and limiting curve shown in Fig. 8 an evaluation for the collapsibility of the investigated soil can be achieved.

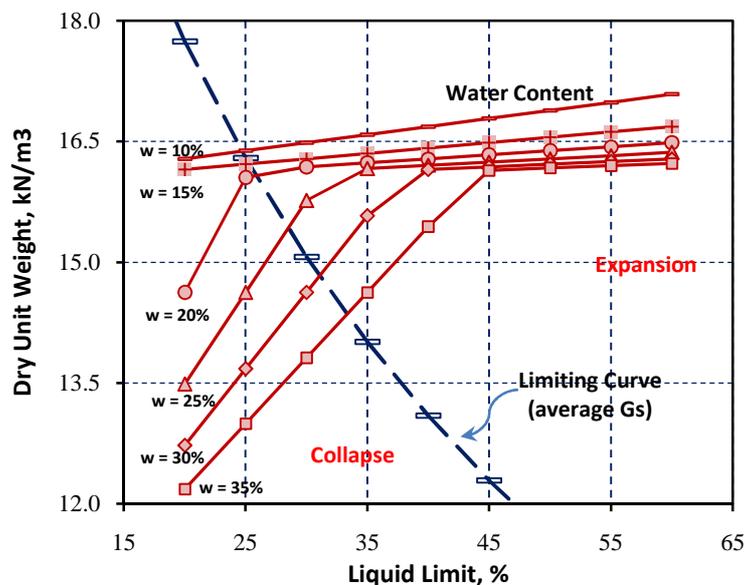


Figure 8. Developed chart for evaluation of collapsibility of Badra, Shatra and Nassirya soil

5. Conclusions

This paper attempts to identify and evaluate major soil types encountered within the area between Badrah, Shatra and Nassirya Cities. An evaluation and estimation of some physical and engineering properties of soil was carried out based on a large number of laboratory test results conducted to determine its index and physical properties. By using advanced statistical analysis software package (NCSS), a mathematical model found to express the relationship between a dependent variable (plasticity index PI, gross plasticity index Pg, and dry unit weight γ_d) and an independent variable (liquid limit LL, plasticity ratio R, and the ratio of liquid limit LL to natural water content w). New line on plasticity chart was established at which PI can be directly obtained with sufficient accuracy if the LL of soil is determined. The swelling characteristics of soil were evaluated, and developed chart to assess suspect soil to swell is modified after Savage, 2007. Identification for the collapsibility is achieved and developed evaluation chart is presented.

Abbreviations

| | |
|------------|---|
| BSN | Badrah, Shatra and Nassirya Cities |
| e_o | Initial void ratio |
| G_s | specific gravity |
| LL | Liquid limit |
| NCSS | Number Cruncher Statistical System |
| P 0.002 | percent of soil fraction with diameter 0.002 mm |
| P 0.425 | percent of soil fraction with diameter 0.425 mm |
| Pg | gross plasticity index |
| PI | Plasticity index |
| PL | Plastic limit |
| R | plasticity ratio |
| W | natural water content |
| γ_d | dry unit weight |
| γ_w | water unit weight |

6. References

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