Scientific Research and Essays Vol. 6(8), pp. 1780-1792, 18 April, 2011
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE10.629
ISSN 1992-2248 ©2011 Academic Journals

Full Length Research Paper

The use of methylene blue test for predicting swell parameters of natural clay soils

Murat Türköz[1]* and Hasan Tosun[2]

[1]Civil Engineering Department, Eskişehir Osmangazi University, 26480, Eskişehir, Turkey.
[2]Agricultural Faculty, Eskişehir Osmangazi University, 26480, Eskişehir, Turkey.

Accepted 20 October, 2010

Swell behavior of clayey soils is referred to as a hidden disaster causing a great deal of damage in light hydraulic structures. In this context, it is of key importance to make a preliminary soil research and to identify soils of this nature through lab tests in order to adopt the correct design strategy. It is extremely important to have determined the swell parameters (swell percentage and swell pressure) in designing light hydraulic structures on swelling soil. In our country, these types of problems that are experienced in light hydraulic structures have been observed generally in construction works of irrigation channels carried out within the framework of Southeastern Anatolia Project. In this study, we examine the facts based on the methylene blue stain test data used in predicting swell parameters of Harran clay soils. Within the frame of the study, methylene blue tests have been carried out besides identification tests; working on undisturbed samples taken from thirty three different points by means of drilling, in an area where irrigation channels are laid intensively. Depending on relevant swell parameters, models developed are based on multiple regression analysis for practical use. In the models developed depending on dry density of soil and methylene blue value, R^2 values are found to be R^2 = 0.93 and R^2 = 0.85 for swell percentage and swell pressure, respectively. In view of the fact that the tests that measure swell parameters are long and costly, these models would be very useful to be able to obtain a preliminary estimate rapidly.

Key words: Harran clay, methylene blue stain test, swell percentage, swell pressure, multiple regression analysis.

INTRODUCTION

There are different types of clay soil; the ones that swell by absorbing water and shrink when dried up. Foundations constructed on these types of soil are exposed to high buoyant forces due to swell behavior of clay. These forces lead to damages in the form of fractures, cracks and bulking in building foundation or in floor elements. Swell behavior of clay soil causes a great deal of damage in light hydraulic structures such as drinking water networks, irrigation pipes or open canal linings, where probability of water leaks, that is to say water-clay contact is high during loading and unloading stages of the system that has minimal dead load. This damage on engineering structures results in significant financial losses. In many countries, design criteria are determined by projects carried out on damages caused due to swelling soil problem (Parker et al., 1977; Chen, 1988; Nelson and Miller, 1992; Abdullah et al., 1999; Al-Rawas et al., 2002; Shi et al., 2002). The potentially expansive soils are generally found in arid and semi arid regions, such as in the Şanliurfa- Harran located in the southeast of Turkey. In Turkey, this problem has often been observed especially for the canal structures constructed in the irrigation areas located in Harran plain, important engineering applications related to the subject have been achieved and knowledge has been obtained (Tosun et al., 2000; Türköz, 2007). Many extensive studies were carried out to analyze the factors affecting the swelling of clayey soils (El-Sohby and El-Sayed, 1981; Azam and Abduljauwad, 2000).

*Corresponding author. E-mail: mturkoz@ogu.edu.tr. Tel: +90 222 2393750/3514. Fax: +90 222 2392840.

The major factors affecting the swelling of such soils are concerned with the physical properties and the mass of soil, such as initial water content, type of clay mineral, initial dry density, and type of coarse grained fraction. Recognition of potentially expansive soils has been a major problem in geotechnical engineering and many methods of identification have been used (Chen, 1988; Nelson and Miller, 1992). Among the mineralogical methods, the dye-adsorption method is relatively simple and widely used. Swelling and shrinking is an intrinsic feature of soil and there is no standard measurement method to directly determine this trait. The most appropriate and the most accurate method used in determining swell potential where swell percentage and swell pressure are evaluated together, is direct measurement. Considering this fact, comparative evaluation of swell behavior of soil is made for soil properties measured under certain conditions. Swell potential is predicted by means of laboratory tests and regression-based empirical equations. The literature contains several empirical equations for swell potential assessment based on index properties obtained mostly in soil identification tests carried out in different times and places. Some researchers believe that swell potential can be correlated with a single parameter. Altmeyer (1955) and Snethen (1980) have suggested classifications that evaluate swell potential as a function of shrinkage limit, plasticity index and shrinkage index, consecutively. Some other researchers have pointed out that three parameters are necessary at least for assessing swell potential (Djedid and Bekkouche, 2001). Komornik and David (1969) have developed a model based on natural water content (w_n), dry unit weight (γ_d) and liquid limit (LL) parameters, to be used in estimating swell pressure, in their statistical work involving 200 samples.

Vijayvergiya and Ghazzaly (1973) have proposed two models for swell pressure prediction based on 270 swell experiments they have made on various soils. Snethern (1984), based on 17 published statistical assessments proposed for identification and classification of swelling soils, has stated that the most consistent and appropriate indicators of swell potential are as such in order: 1) Liquid limit and plasticity index, 2) liquid limit and natural water content correlation, 3) shrinkage limit and plasticity index, 4) shrinkage limit and linear shrinkage. On swell behavior assessment of clay, Djedid and Bekkouche (2001) have declared that among the parameters determined by identification tests, the most important are the plasticity index, the percentage of clay particles, the methylene blue value and the shrinkage limit. However, Chen (1988), and Sridharan and Prakash (1998) have shown that shrinkage limit cannot be used in estimating soil swell potential since, the mechanisms that conduct shrink and swell are completely different. Locat et al. (1984) studied soils coming from nine sites in Eastern Canada. They determined the correlation coefficients (r) of the relationships between specific surface area values (determined from the result of methylene blue test) and clay content, liquid limit, plastic limit and plasticity index. The correlation coefficients (r) of these relationships are 0.69, 0.89, 0.63 and 0.92, respectively.

Within the scope of this study, a site specific geotechnical study has been held in order to determine the swell behavior of the soil that forms a foundation for present water conduits and to verify the swelling soil problem sensitivity of future roads, buried structures and one ore two story buildings. With this purpose, undisturbed soil samples were taken by drilling at thirty three different locations where irrigation channels are in multitude at Harran plain. Swell parameters of these samples are determined by direct tests and the effect of physical properties and the methylene blue value (MBV) are examined. The results are evaluated together with models developed by multiple regression analysis. In the light of these evaluations, it is seen that in-situ dry density and MBV variables can be used at considerable level in predicting swell parameters of related models.

MEYHYLENE BLUE TEST

Methylene blue test was developed in France for determining the suitability of granular material in manufacturing concrete whilst detecting clay content of granular material. Methylene blue powder behaves like a cationic dye when mixed with water and is identified with the chemical formula: $C_{16}H_{18}N_3SCl$. When mixed with soil solution, chloride ions in methylene solution change place with cations in clay minerals to be adsorbed on the surface of clay minerals. The amount of adsorbed methylene solution varies according to the amount of clay minerals and clay type, cation exchange capacity and specific surface area. Methylene blue test is a popular test method since it does not require particular equipment and is rather straightforward in practice. Methylene blue adsorption test is a reliable and simple method to obtain information on the presence and properties of clay minerals in soils, especially in the first stages of research (Verhoef, 1992). Two test methods have been used in practice, namely, the “turbidimetric” method and the “spot method”. The spot method is a simplified titration technique. A certain concentration of methylene blue solution is added in definite volumes to a suspension of fine grained soil. The total amount of methylene blue solution adsorbed is used for the calculation of methylene blue value (MBV). The method is very commonly used in engineering practice (Nevins and Weintritt, 1967; Taylor, 1985; Hills and Pettifer, 1985; Verhoef, 1992).

Index properties (liquid limit, plasticity index, etc.) which can be easily correlated with methylene blue value allow making important evaluations particularly for preliminary site investigations. Cation exchange capacity (Taylor, 1985; Çokça and Birand, 1993b), specific surface area (Chiappone et al., 2004; Yukselen and Kaya, 2008) and swell potential (Çokça, 1991, 2002; Çokça and Birand, 1993a) can be assessed by methylene blue test. Methylene blue stain test enables determining ion adsorbtion capacity of the soil by verifying the amount of methylene blue required to cover the entire surface area of clay particles in the soil. This test method is based on titration developed by chemical reaction between free methylene blue cations acquired by dissolving methylene blue in water and interchangeable clay cations. Clay particles with the largest specific surface area and the highest negative electrical charge have the biggest capacity for cation exchange. Adsorbtion capacity increases as a function of specific surface area and electrical charge of the clay particle. Chiappone et al. (2004) the French Norme Française NF P 94-068 (AFNOR, 1993) and the American C837-99 (ASTM, 1984) have carried out a series of comparative studies on practicality and evaluation of methylene blue test used in identifying clay minerals as stated in standards. For ANFOR standard analysis, it is recommended to take soil test samples considering their clay content; with 30 to 60 g in clayey or excessively clayey soils and 60 to 120 g in less clayey soils. Test procedure follows as such:

Soil samples taken at this ratio are dissolved in 500 ml distilled water; each time 5 ml of methylene blue solution prepared with 10 g/L concentration is added to the soil sample solution. 1 min later, one drop of the mixture solution is placed onto filter paper. The test is ended when the dye forms a second lighter colored blue halo around the aggregate-dye spot and stays stable for 5 min.

ASTM Standard, based on the same test procedure as ANFOR standard, involves use of 2 g of soil sample and the analysis is carried out in acidic milieu (pH ranges between 2.5 and 3.8). Ultimately, it is stated that (Chiappone et al., 2004) ASTM standard test method is suitable to employ for homogenous, fine-grained material; in other words, solely verifying the clay content whereas ANFOR standard defined test method yields outcomes that represent the entire material, thus should be used in heterogeneous samples.

Preparation of methylene blue solutions and test procedure

Methylene blue tests performed in this context are based on the French Norme Française NF P 94-068 (AFNOR 1993) standard. Methylene blue solution is made by dissolving methylene blue powder in distilled water. It is prepared by mixing to dissolve 10 ± 0.1 g of methylene blue in 1 L of distilled water in a beaker at room temperature, for one hour. Soil solution is prepared by mixing 7.5 g (or 30 g) of soil sample passing sieve No.40 in 50 ml distilled water (200 ml for 30 g soil sample) in a beaker with a mixer running at 700 rpm for 5 min (Çokça, 1991).

Analysis basics

The mixture made by adding increasing amounts of methylene blue solution to soil solution is pipetted and dropped onto standard filter paper. 5 ml of methylene blue solution is mixed with soil solution. From this moment on, mixer speed must be adjusted to 400 rpm to remain at this speed until the end of the test. At the end of one minute, an amount of mixture is taken using a glass pipette and dropped onto filter paper. The filter paper should be placed on a beaker or other appropriate support so that the wetted surface does not touch any solid or liquid. Generally at the stage of placing the first drop on the filter paper, a dark blue spot surrounded by a colourless moist halo is observed (this means that the test is negative).

5 ml of methylene solution is added each time to the soil solution until a halo of light blue dye surrounds the dark blue spot on the filter paper. At this point no more methylene blue solution is added and the mixture is inspected for 5 min in total, checking at each 1 min intervals to determine the permanence of the light blue halo. At the end of the test, the light blue halo around the dark blue spot is surrounded by a zone of clear water (meaning that the test is positive). This indicates that there is excessive amount of methylene blue that is no longer adsorbed by clay mineral and that is remains in suspension. At this point, no more methylene blue is added and the suspension is checked at 1 min intervals to determine the stability of the light blue halo. If the light blue ring that surrounds the spots dropped in intervals of 1 min disappears, then the methylene solution amount to be added should be reduced to 2 ml to follow the same procedure.

Figure 1 illustrates methylene blue stain test flow diagram. The methylene blue value (MBV) is normally expressed in grams. Methylene blue adsorbed by 100 g of sample material, mostly given as g/100 g. The MBV of a sample is calculated by the following formula:

$$MBV(g/100g) = V_{CC}(mL) / f'(g) \quad (1)$$

Where V_{cc} = volume of methylene blue solution injected to the soil solution (ml), f'= dry weight of the sample used (g).

EXPERIMENTAL WORKS

Study area is located in the south of Urfa province of Southeastern Region and lengthened through Syria from north to east between 38° 48' E longitude and 37° 2' N latitude. Related area, starts near the Urfa-Mardin highway, opens out to Syria in east (Figure 2). Crimson red color “Harran clay”, the subject of this study, found within the site of investigation is formed by disintegration of sedimentary and volcanic rocks of the region. Harran plain

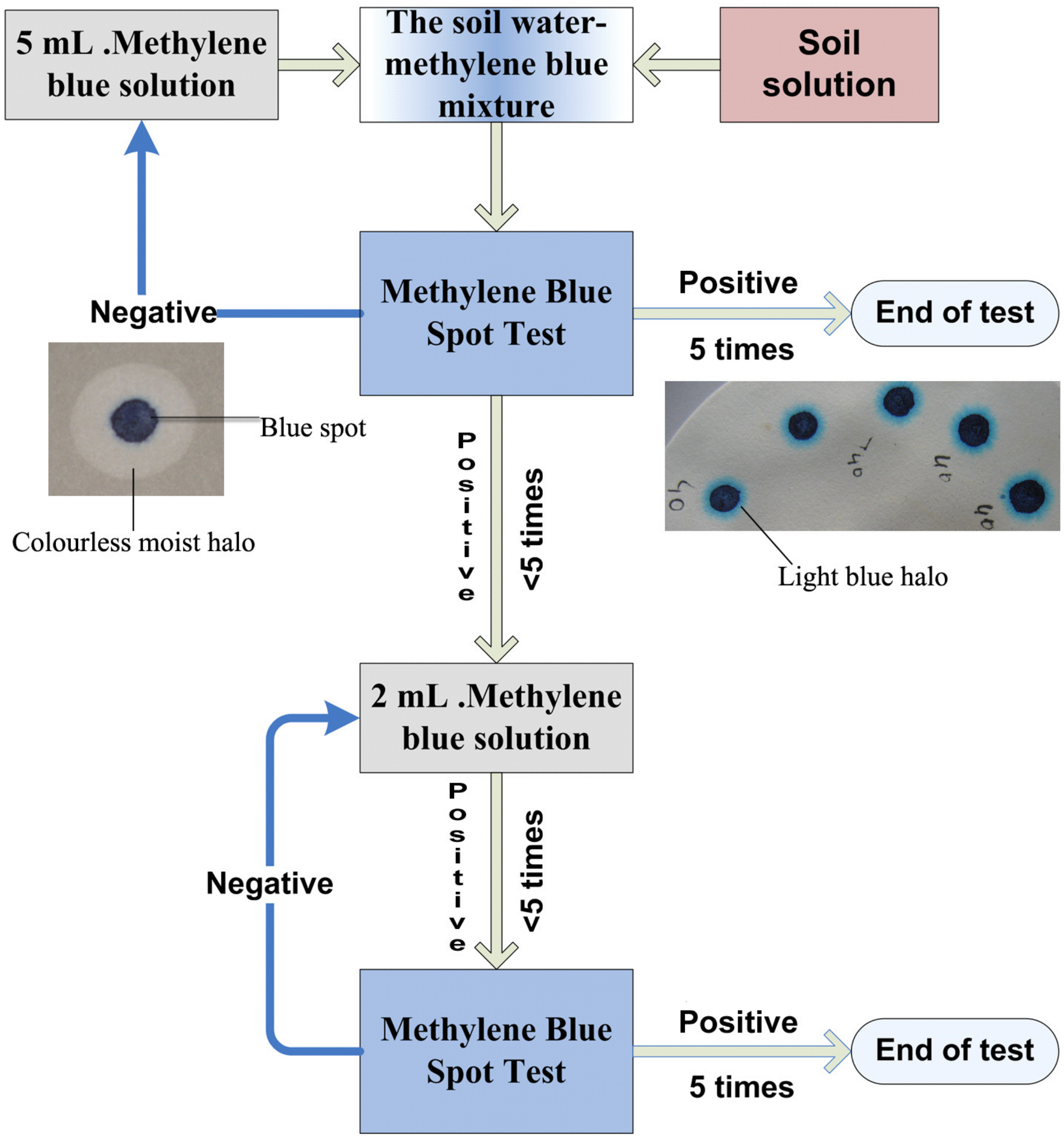

Figure 1. Methylene blue stain test flow diagram.

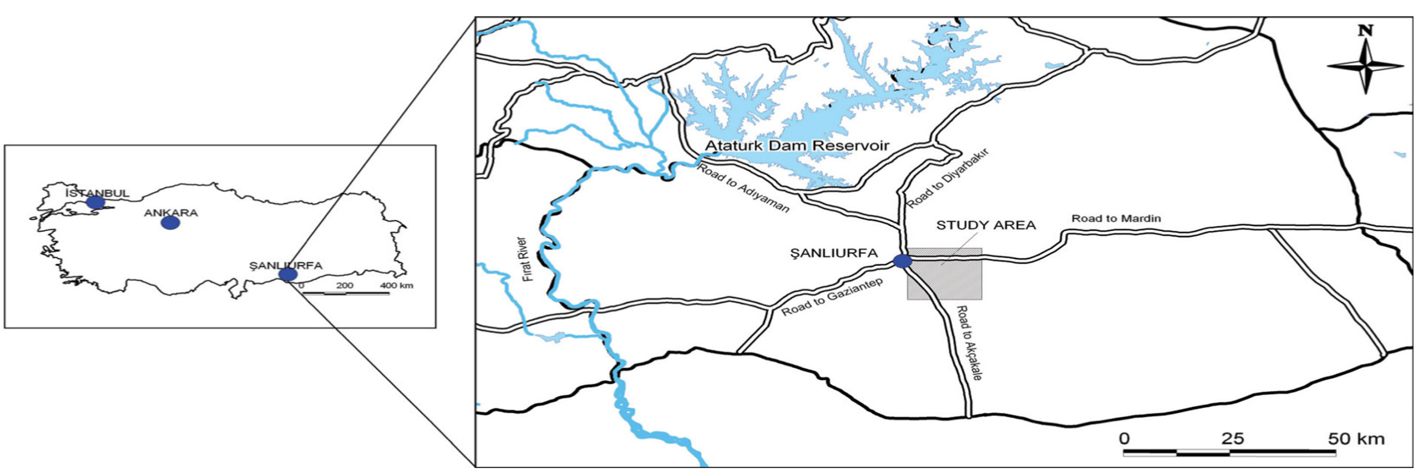

Figure 2. Location map of the study area.

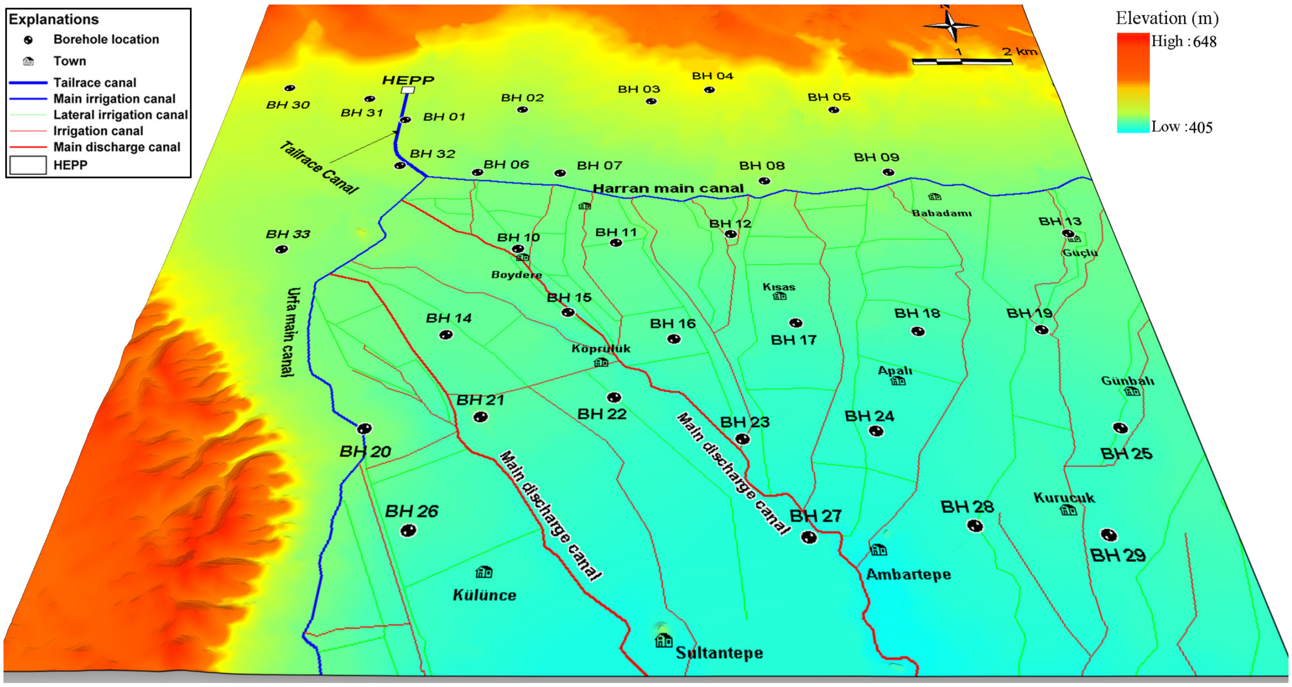

Figure 3. 3D view and the borehole locations of the study area.

accommodates sedimentary and volcanic rocks. Sedimentary rocks found in the site of investigation are namely (from old to young): Paleocene old age marn, Eocene old age limestone, Miocene old age argillaceous limestone and detritic material such as clay, sand and gravel (Tosun, 2004). As for volcanic rocks, basalt covers a vast area that originates from Karacadağ volcanism. The sedimentation basin formed as the result of tectonic activity is filled with disintegrated and carried material. Undisturbed samples have been collected from thirty three different locations by drilling at the level of 1.5 to 2.0 m below the surface in order to evaluate the swell behavior of disintegrated and carried material where numerous irrigation plants are build upon at Harran and Şanliurfa plains (Figure 3).

Primarily, identification and classification properties of these samples have been determined, methylene blue test is made for verification of chemical properties and then direct tests have been carried out in order to verify swell parameters.

Material properties and identification tests

Tests carried out within this framework are made on samples obtained by Shelby tube samplers. Grain size analyses, hydrometer analyses and Atterberg limit tests were performed in order to classify the samples according to the Unified Soil Classification System (USCS). In the next stage percentage of gravel, sand and fines (silt-clay) are determined (Figure 4). The tests were performed following the American Society of Testing Materials (ASTM) D422-63 and D4318-00 (2003) respectively. The statistical evaluation on the 33 samples studied is given in Table 1. It may be seen that the liquid limit varied from 52 to 72%, the plasticity index varied between 23 and 39%. The standard deviation of the mentioned samples is very low. Related samples are classified as "high plasticity clay (CH)" according to the USCS. Chen (1988) classified soil with plasticity index (PI) over 35% as having very high swell potential, 29 to 35% as high, 10 to 35% as medium and 0 to 15% as low. Figure 5. Proposed by Daksanamurthy and Raman (1973) provides an indication of the potential for expansion and suggests that the clay samples are highly to very highly expansive. Generally, the higher the plasticity index and liquid limit of a soil, the higher the swell potential. Figure 6 relates expansion potential to liquid limit and in-situ dry density based on the experience of the U.S. Bureau of Reclamation (FHWA-IF-02-034, 2002).

On the data obtained from undisturbed soil samples being evaluated for initial assessment of the expansion potential of the soils, the foundation soils creating swell problem are generally highly plastic clayey soils according to this Figure 6.

Swell tests

Early identification during site investigation and laboratory testing is extremely important to ensure that the correct design strategy is adopted. Swelling and shrinkage, which are the internal properties of soil, there are not any direct standard methods in order to measure these properties. In this respect, comparison of soil under certain conditions is considered for evaluating the behavior of swelling. Direct measurements are the most appropriate and successful methods for determining swell parameters. These methods are; evaluation of free swelling, expansion index (EI), potential volume change (PVC) and odometer test methods under laboratory conditions. Within the frame of this work, swell percentage and swell pressure tests are performed on samples taken at 33 different locations by hydraulic jack from undisturbed (UD) tube samplers, using direct methods. The PVC meter test is not conducted to any standard specifications. In this study, the method mentioned in Lambe's study was used (Lambe, 1960). According to the Lambe's study, PVC meter equipment is used in measuring swell pressure. The basic of PVC meter test is to determine the swell pressure that develops by preventing the swell formed after wetting the soil sample. The sample is placed in the system so as to locate the proving ring on the sample. The sample is soaked with water and proving ring dial readings are taken at certain intervals. The value indicated on proving ring dial is

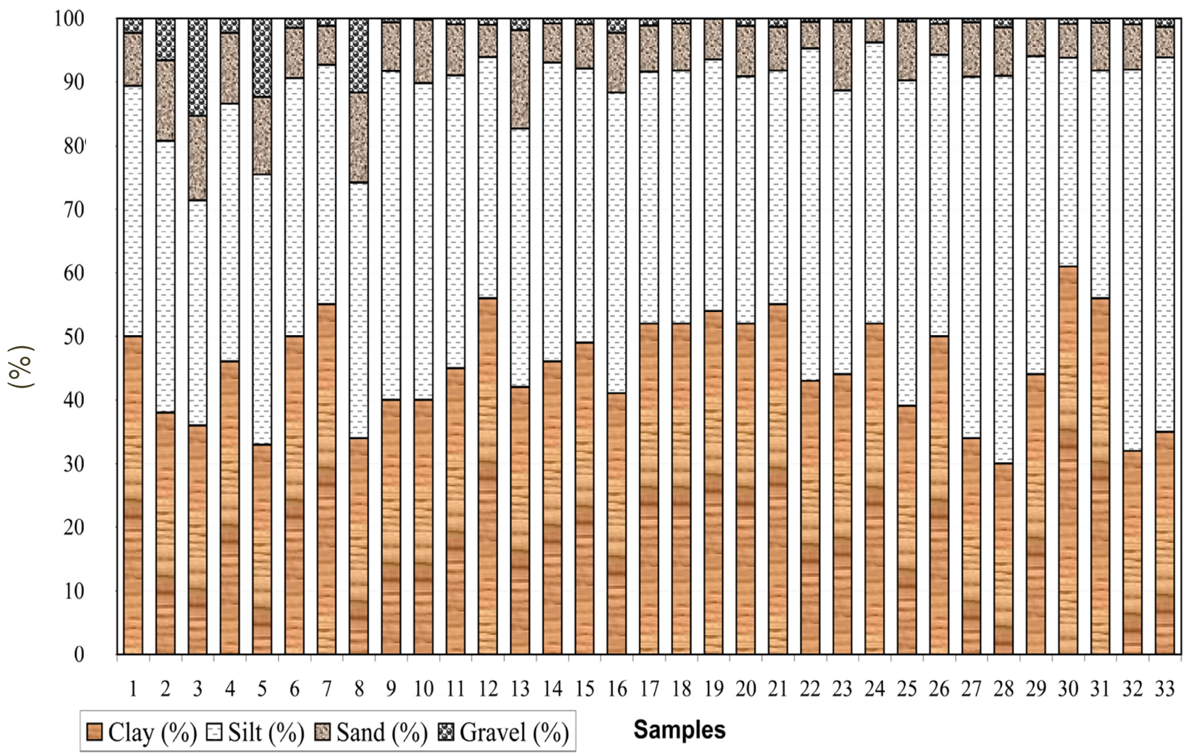

Figure 4. Granulometry chart of the samples.

Table 1. The statistical data for physical properties of the samples.

Property	Number	Value			
		Minimum	Maximum	Mean	Standard deviation
In situ dry density, (Mg/m^3)	33	1.465	1.685	1.531	0.051
Natural water content, (%)	33	18.9	30.1	25.63	2.658
Clay, (%)	33	30.0	61.0	45.03	8.282
Silt, (%)	33	32.8	60.9	44.49	7.390
Sand, (%)	33	3.8	15.5	8.19	2.913
Gravel, (%)	33	0.0	15.4	2.29	3.707
Liquid limit, (%)	33	52.0	72.0	60.55	5.646
Plastic limit, (%)	33	25.0	36.0	29.15	2.438
Plasticity index, (%)	33	23.0	39.0	31.39	4.085
Liquidity index	33	-0.30	0.11	-0.11	0.100
Specific gravity	33	2.72	2.83	2.78	0.025

multiplied by proving ring dial gauge conversion factor in order to convert into common load unit. Pressure is determined by dividing the load to the sample surface area.

Expansion index (EI) measurement test are conducted in accordance with (ASTM) D4829 (1988). Swell percentage, one other significant variable of swell parameters, is defined as the ratio of ultimate deformation developed in 24 h under 7 kPa pressure or until swell is complete over the initial size of the sample. However, it is required to modify the equipment mentioned in (ASTM) D4829 (1988) in order to enable working on samples of identical diameter and height and making comparisons that make sense for swell potential variables. With this principle, expansion index (EI) measurement equipment is duly converted. In this way, weight elements are manufactured in order to apply 7 kPa pressure on samples taken into rings of 7 cm diameter and 2 cm height, with thin wall thickness. Immediately after soaking the samples with water, swell percentage and the changes in swell pressure are measured via digital measurement devices particularly designed for this purpose that are connected to the system for different time intervals (0.5, 1, 2, 4, 8, 16, 32, 60, 120, 240, 360 and 1440 min). Swell percentage of samples are found to vary between 0.5 and 10% depending on their dry density and initial water content, with an average of 2.67 and a standard deviation of 2.26.

Swell pressures of the same samples are determined to be between 4 kPa and 102.2 kPa, with an average of 24.45 kPa and a standard deviation of 19.41 kPa.

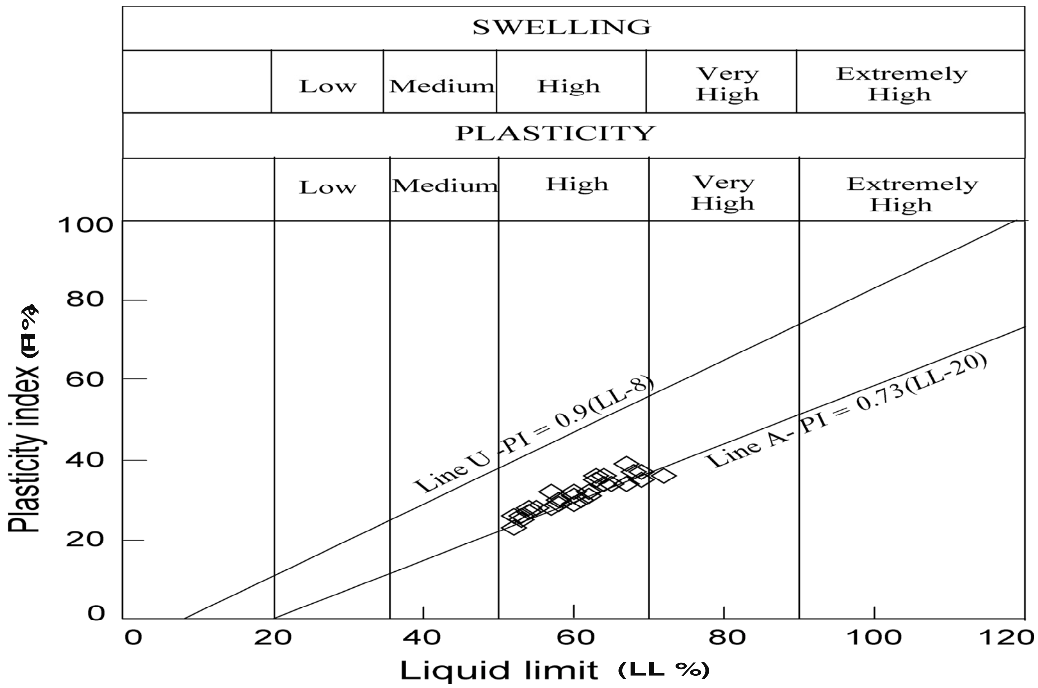

Figure 5. Casagrande's chart modified by Daksanamurty and Raman (1973) for the evaluation of plasticity and swelling

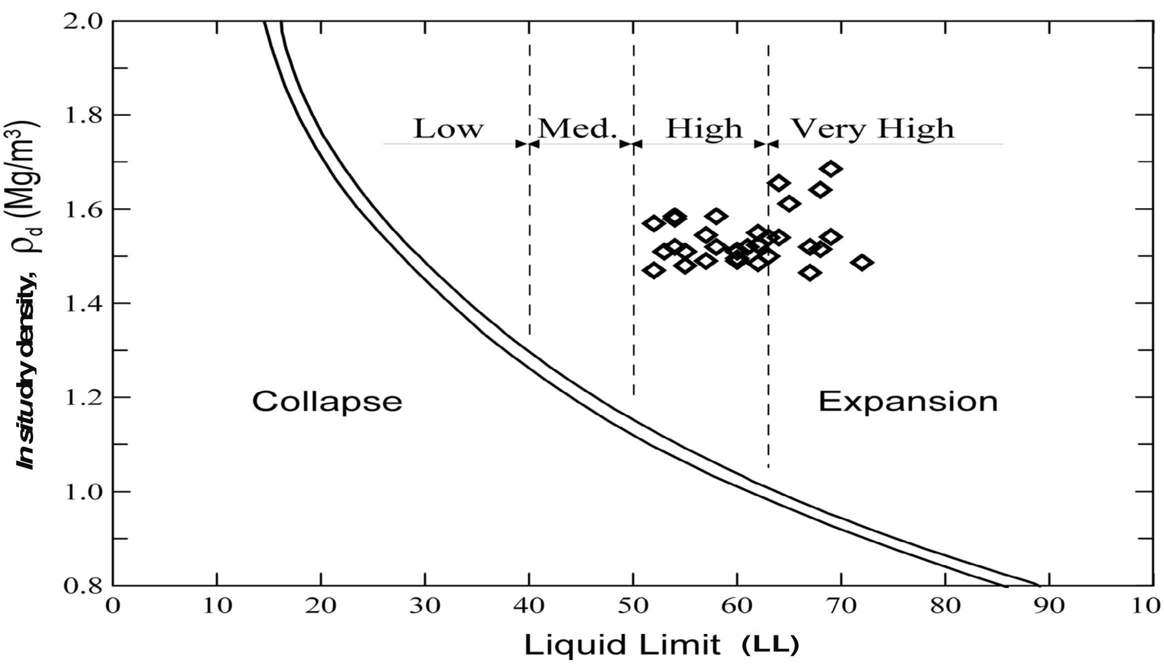

Figure 6. Guide to collapsibility, compressibility, and expansion based on *in situ* dry density and liquid limit.

Methylene blue tests

Methylene blue tests, as mentioned before, are carried out under laboratory conditions of identical character and the same ambient temperature to prevent structural variations in clay and methylene blue powder that may happen to occur due to temperature changes. Besides, in order to eliminate the effect of grain size distribution on test results and to provide a uniform distribution, all samples are sieved through No.40 sieve (400 µm) prior to the test. Finally, methylene blue value is determined for each sample using Equation 1. Methylene blue tests results of this project reveal the following: methylene blue values vary between 5.33 and 11.30

Table 2. Correlation matrix for the properties of the samples.

	ρ_d	w_n	LL	PL	PI	Silt	Clay	Ac	LI	Gs	S_P	P_s	MBV
ρ_d	1												
w_n	-0.355	1											
LL	0.168	0.354	1										
PL	-0.015	0.290	0.768	1									
PI	0.242	0.316	0.924	0.464	1								
Silt	-0.165	0.083	-0.290	-0.310	-0.215	1							
Clay	0.130	0.389	0.649	0.479	0.611	-0.711	1						
Ac	0.019	-0.141	0.030	-0.169	0.142	0.711	-0.685	1					
LI	-0.210	0.716	-0.132	-0.438	0.078	0.295	0.087	0.008	1				
Gs	0.011	0.166	0.207	0.227	0.151	0.139	0.156	-0.081	0.020	1			
S_P	0.908	-0.198	0.410	0.290	0.394	-0.231	0.285	-0.022	-0.279	0.084	1		
P_s	0.845	-0.154	0.372	0.243	0.369	-0.166	0.267	-0.019	-0.211	0.128	0.939	1	
MBV	0.230	0.216	0.819	0.619	0.763	-0.394	0.676	-0.142	-0.156	0.250	0.522	0.555	1

ρ_d = *in situ* dry density (Mg/m^3), w_n = natural water content (%), LL = liquid limit (%), PL = plastic limit (%), PI = plasticity index (%), Silt (%), Clay (%), Ac = activity, LI = liquidity index, Gs = specific gravity, S_p = swell percentage, P_s = swell pressure (kPa) and MBV = methylene blue value (g/100 g).

(g/100 g), with an average of 7.36 and the standard deviation value varying in a narrow range, with 1.43.

MULTIPLE REGRESSION ANALYSIS

When statistical equations are considered, one by one evaluation of parameters becomes complicated in verifying the effect of parameters determined at the end of the experimental study on swell parameters. In this sense, the foremost advantage of correlation and regression is not only the fact that shows the total effect of independent variables but also that the effect of each and every variable can be observed by keeping other variables constant (Thomas et al., 2000). By calculating the multiple correlation matrix of all variables, the correlation between independent variables as well as the correlation between independent variables and each dependent variable that are swell percentage and swell pressure are evaluated. Multiple correlation evaluation between dependent and independent variables are presented (Table 2). The correlation matrix shown in Table 2 describes the level of association between the swelling parameters on one hand and the MBV parameters and index properties, on the other hand. R^2 values, the most common measurement and identification coefficient of precision of the linear model and the indicator of instructive supremacy of regression model, are evaluated one by one on equation basis.

Regression equations for swell percentage and swell pressure are developed as follows:

Swell percentage, S_p:

$$S_P = -57.965 + 37.076\rho_d + 0.524\text{MBV} + \varepsilon \quad (2)$$

Swell pressure, Ps:

$$P_S = -457.817 + 290.015\rho_d + 5.178\text{MBV} + \varepsilon \quad (3)$$

Where ρ_d is *in situ* dry density in mg/m^3; MBV is methylene blue value in g/100 g; ε is the mean-zero Gaussian random error term.

The coefficient of determination, R^2, obtained for Equation 2 is 0.928 and the corresponding adjusted value is 0.923. The overall F-statistic is 192.272. For Equation 3, the resulting R^2 value is 0.851 while the adjusted R^2 is 0.841 and the overall F-statistic was obtained as 85.829. The t-statistic as well as the corresponding p-value and 95% confidence interval for coefficients for each of the equations are shown in Table 3. Each of the variables in the equation is significant at 5% level (that is, $\alpha = 0.05$) as the p-values are less than 0.05. The measured values of swell percentage as well as swell pressure are compared to the respective predicted values in turn and are shown in Figures 7 and 8, respectively. The figures show that the predicted values are very close to the measured values.

DISCUSSION

The parameters determined from swelling soil identification tests have been combined in a number of different classification schemes. Seed et al. (1962), in an extensive study on swelling characteristics of compacted clays, have developed a chart based on activity and percent clay size. According to the soil classification chart considering activity and clay content proposed by Seed et al. (1962), samples have medium and high potential of

Table 3. Results of regression analyses.

Parameter	Variables	Coefficients	*t*-statistics	*p*-value	95% confidence interval for coefficients	
					Lower	Upper
	Intercept	-57.965	-17,241	0.00	-64.831	-51.099
Swell percentage, S_p	Dry density	37.076	16.477	0.00	32.480	41.671
	MBV	0.524	6.566	0.00	0.361	0.687
	Intercept	-457.817	-11.056	0.00	-542.386	-373.248
Swell pressure, P_s	Dry density	290.015	10.464	0.00	233.414	346.616
	MBV	5.178	5.271	0.00	3.171	7.184

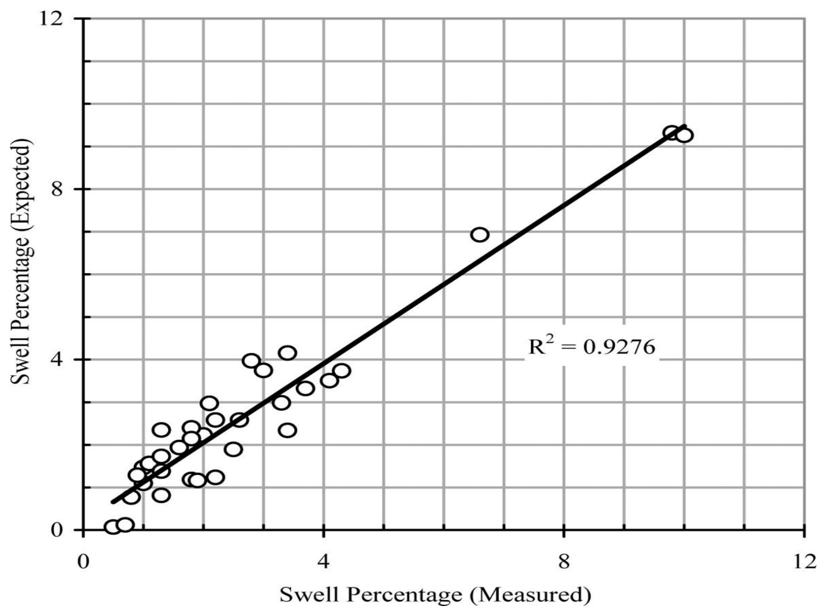

Figure 7. Relationship between the estimated and measured swell percentage.

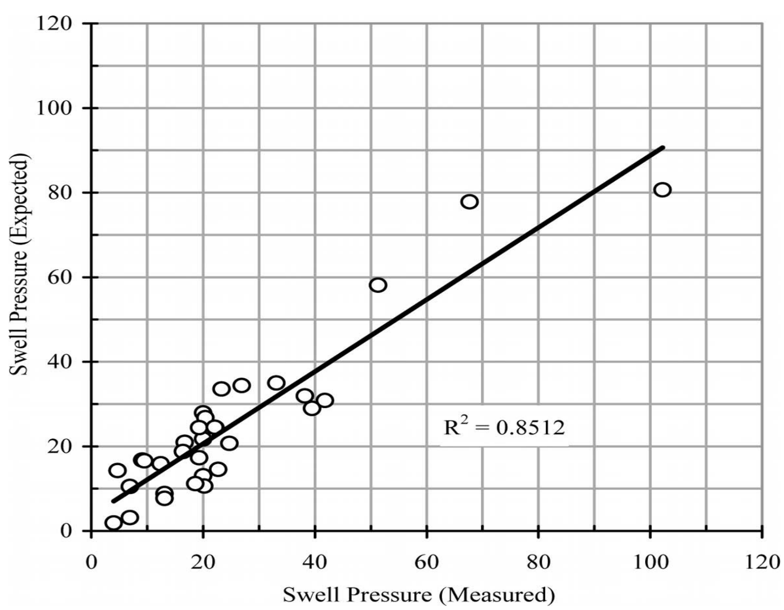

Figure 8. Relationship between the estimated and measured swell pressure.

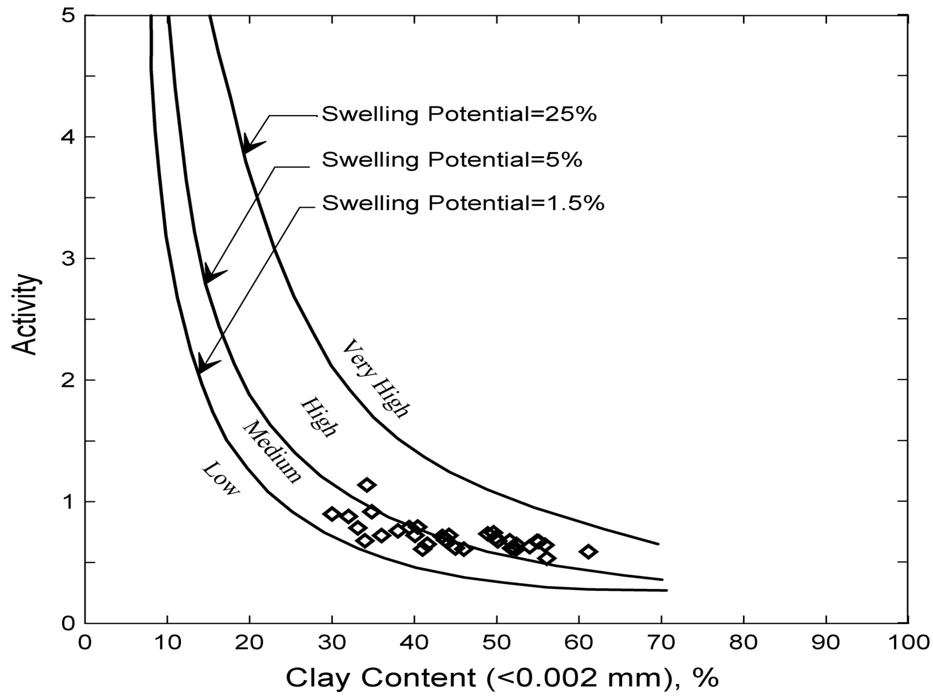

Figure 9. Degree of swell potential classification chart according to Seed et al. (1962).

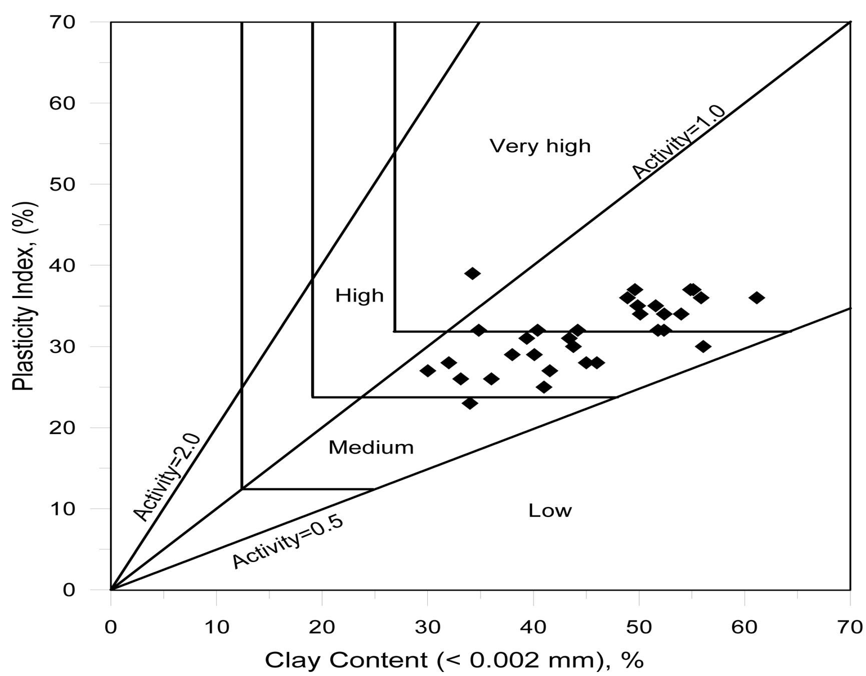

Figure 10. Distribution of the Harran clay samples on activity and swell potential chart proposed by Van der Merve (1964).

swelling (Figure 9). Also, another method developed by Van der Merwe (1964) is based on plotting the plasticity index against clay content. Distribution of the samples on the swell potential chart of Van der Merwe (1964) indicated that 3% of the samples have medium swell potential, 58% have high swell potential, 39% have very high swell potential (Figure 10). The differences between the charts can be attributed to different initial soil conditions and different initial water contents. For the same soil sample both of these classification methods

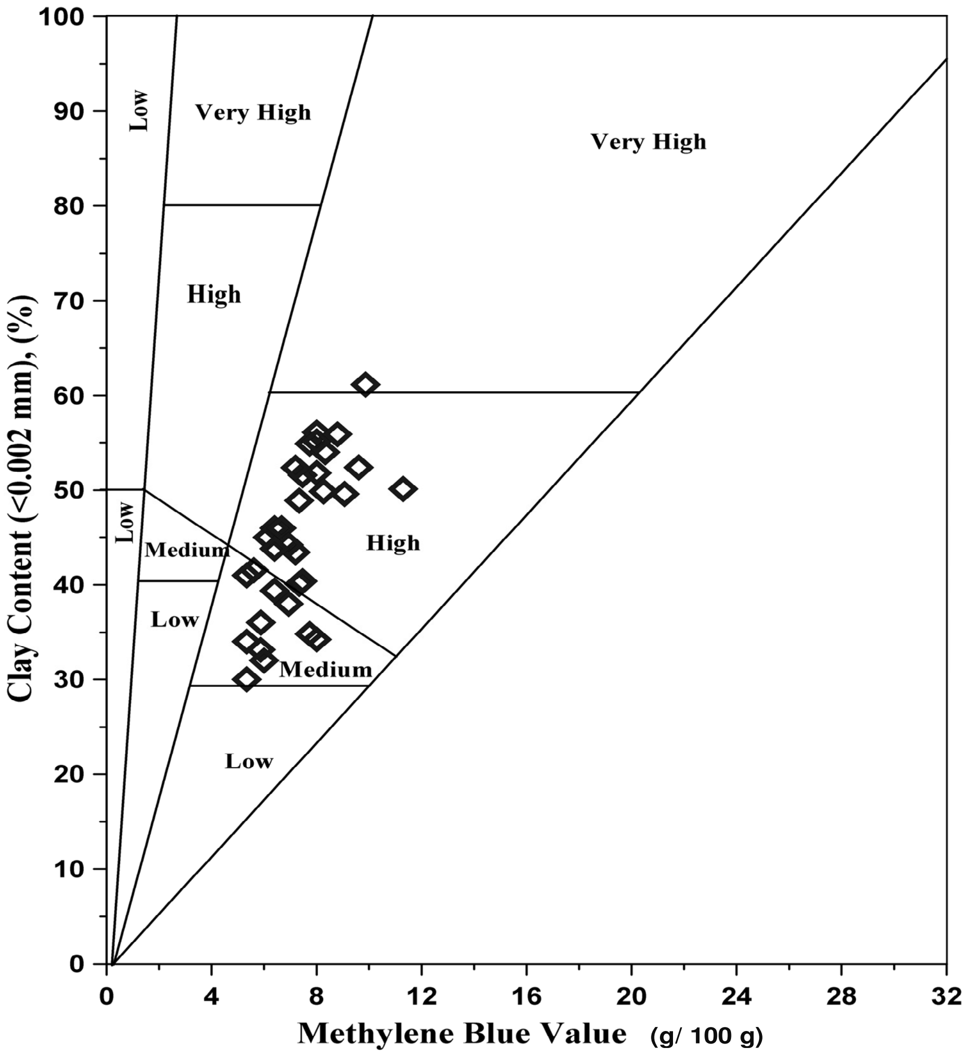

Figure 11. Swell potential classification chart proposed by Çokça (1991).

may give different swell potential value. Therefore such correlations have to be derived locally. It is evident that undisturbed soil sampling is a prerequisite for detailed research in determining swell potential after making certain definitions based on physical properties and carrying out regional soil profile investigations for soils that may be risky in terms of swell potential. The classification chart based on MBV – Clay content correlation, proposed by Çokça is presented in Figure 11. In the same figure it is clearly seen that the soil samples are in possession of medium and high swell potentials, which is compatible with the classification chart suggested by Seed et al. (1962). It is found that Seed et al. (1962) definition of swell potential is valid for undisturbed Harran clay. In the respect of these evaluations, it is obvious that methylene blue value can be used as an alternative to the parameters used in primary evaluation of swell potential such as clay content, liquid limit and plasticity index. Furthermore, the fact that methylene blue test is much more user friendly, requiring less time than the experimental studies used in determining swell potential of clay soils, is one other advantage of this test method.

Consequently, in this study where undisturbed samples are used, models developed based on MBV variables and dry density, allow estimating in-situ soil swell parameters at considerably tangible levels. Considering the fact that the tests which measure swell parameters are long and costly, it would be useful to estimate preliminary swelling parameters with only conducting MBV and dry density tests.

Conclusion

In this study, swell percentage and swell pressure of clay soils with high plasticity are determined through direct tests and the effect of various physical parameters and particularly the effect of methylene blue value on these data is studied. Using the results obtained, evaluations are made based on multiple regression analysis:

i) Harran clay with very high liquid limits has high to very high activity and exhibits high swell parameters which result in damage to light structures.
ii) Swelling clays are the main cause of damage to light hydraulic structures at the study site due to the highly swelling nature of the soil, flat topography resulting in poor drainage, arid and semi arid climate, poor construction methods and ineffective precautions. Therefore, new models are required to be developed in order to evaluate the swelling potential.
iii) Absolute errors are observed in mathematical models developed for predicting *in situ* swell percentage and swell pressure. The fact that the soil is a material of three phases and that all its variables cannot be controlled at the same time, lead to uncertain conditions which cause these errors. However, evaluations must be based on undisturbed samples that represent the given case for correct prediction.
iv) Simple mathematical models depending on in-situ dry density and methylene blue value have been developed for controlling swell parameters of natural clay soils. These mathematical models can be used for designing light hydraulic structures on the soil having a liquid limit, which ranges between 52 and 72%.

An ordinary site investigation usually does not provide sufficient data for evaluating swell potential. Therefore, more detailed and site specific investigation methods are required to determine the presence of swelling soils. Considering vast lands, it is evident that detailed site investigation demands a great deal of funds, equipment, qualified staff and time. In this sense, it will be much more practical to utilize the models proposed in this study for this region.

ACKNOWLEDGEMENTS

This study was supported by State Planning Organization Foundation Grant No: 2004K120770. Authors would like to thank authorities of the 15th Regional Directorate of State Hydraulic Works.

REFERENCES

Abdullah WS, Alshibli KA, Al-Zou'bi MS (1999). Influence of pore water chemistry on the swelling behavior of compacted clays. Appl. Clay Sci., 15: 447- 462.

AFNOR (1993). Mesure de la quantité et de l'activité de la fraction argileuse (Norme Française NF pp. 68-94). Association française de Normalization (ANFOR), La Défense, Paris, France.

Al-Rawas AA, Taha R, Nelson JD, Al-Shap TB, Al-Siyabi H (2002). A comparative evaluation of various additives used in the stabilization of expansive soils. Geotech. Testing J., 25(2): 199-209.

Altmeyer WT (1955). Discussion of engineering properties of expansive clays. J. Soil Mech. Found. Div., ASTM, 81(SM2): 17-19.

ASTM D (1988). Standard test method for expansion index of soils. Annual Book of ASTM Standards, PA 4829: 4-8.

ASTM D (2003). Standard test method for particle-size analysis of soils. Annual Book of ASTM Standards, PA, 4(8):10-17, 422-463.

ASTM D (2003). Standard test methods for liquid limit, plastic limit, and plasticity index of soils, Annual Book of ASTM Standards, PA, 4.(8): 482-593, 4318-43100.

Azam S, Abduljauwad SN (2000). Influence of gypsification on engineering behavior of expansive clay. J. Geotech. Geoenviron. Eng., 126(6): 538-542.

Çokça E (1991). Swelling potential of expansive soils with a critical appraisal of the identification of swelling of Ankara soils by methylene blue tests. PhD. Thesis, Department of Civil Engineering, Middle East Technical University, Ankara, Turkey, p. 246.

Çokça E (2002). Relationship between methylene blue value, initial soil suction and swell percent of expansive soils. Turkish J. Eng. Environ. Sci., 26: 521-530.

Çokca E, Birand AA (1993a). Prediction of swelling potential of Ankara soils by methylene blue test. Doğa- Turkish J. Eng. Environ. Sci., 17: 57-63.

Çokca E, Birand AA (1993b). Determination of cation exchange capacity of clayey soils by the methylene blue test. Geotech. Testing J., 16 (4): 518-524.

Chiappone A, Marello S, Scavia C, Setti M (2004). Clay mineral characterization through the methylene blue test: comparison with other experimental techniques and applications of the method. Can. Geotech. J., 41: 1168-1178.

Daksanamurty V, Raman V (1973). A simple method of identifying an expansive soil. Soils and Foundation, Jap. Soc. Soil Mech. Found. Eng., 13(1):97-104.

Djedid A, Bekkouche A (2001). Identification and prediction of the swelling behaviour of some soils from the Tlemcen region of Algeria, Bulletin Des Laboratoires Des Ponts Et Chaussées, Ref., 4375: 69-77.

El-Sohby MA, El-Sayed AR (1981). Some factors affecting swelling of clayey soils. Geotech. Eng. 12: 19-39.

FHWA-IF-02-034 (2002). Geotechnical engineering circular, Evaluation of soils and rock properties. Federal Highway Administration, U.S. Department of Transportation. p. 5.

Hills JF, Pettifer GS (1985). The clay mineral content of various rock types compared with the methylene blue value. J. Chem. Tech. Biotechnol., 35A: 168-180.

Komornik A, David D (1969). Prediction of swelling pressure of clays. J. SMFE Div., ASCE, 95(SM1): 209-225.

Lambe TW (1960). The character and identification of expansive soils, soil PVC meter. Federal Housing Administortion. Technical Studies Program. FHA, p. 701.

Locat J, Lefebvre G, Ballivy G (1984). Mineralogy, chemistry and physical properties interrelationships of some sensitive clays from Eastern Canada. Can. Geotech., 3(21): 530-540.

Nelson JD, Miller JD (1992). Expansive soils-problems and practice in foundation and pavement engineering. J. Willey and Sons. New York, p. 259.

Nevins MJ, Weintritt DJ (1967). Determination of cation exchange capacity by methylene blue adsorption. Ceramic Bull., 46(6): 587-592.

Parker JC, Amos DF, Kaster DL (1977). An evaluation of several methods of estimating soil volume change. Soil Sci. Soc. Am. J., 41: 1059-1064.

Seed HB, Woodward RJ, Lundgren R (1962). Prediction of swelling potential for compacted clays. J. Soil Mech. Found. Div (ASCE), 88(3): 53-87.

Shi B, Jianh H, Liu Z, Fang HY (2002). Engineering geological characteristics of expansive soils in China. Eng. Geol., 67: 63-71.

Snethen DR (1980). Characterization of expansive soils using soil suction data. Proceedings of 4th International Conference on Expansive Soils, Denver, 1: 54-75.

Sridharan A, Prakash K (1998). Mechanism controlling the shrinkage limit of soils, Geotech. Testing J., ASTM, 21(3): 240-250.

Snethen DR (1984). Evaluation of expedient methods for identification and classification of potentially expansive soils. Fifth International Conference on Expansive Soils, Adelaide, South Australia, 21-23

May: pp. 22-26.
Taylor RK (1985). Cation exchange in clays and mudrocks by methylene blue. J. Chem. Technol. Biotechnol., 35A: 195-207.
Thomas PJ, Baker JC, Zelazny LW, Hatch DR (2000). Relationship of map unit variability to shrink-swell indicators. Soil Sci. Soc. Am. J., 64: 262-268.
Tosun H, Türköz M, Zorluer I, Arslan A (2000). Controlling the swelling potential of expansive soils by compacting control and a case study. Proceeding of 3rd National Congress on Southeast Anatolian Project, Sanliurfa: pp. 425-432 (in Turkish with English abstract).
Tosun H (2004). An empirical method for controlling the swell potential of compacted soils. Geotech. Eng., 35(3):141-148.
Türköz M (2007). Determination of swelling potential of high plasticity clays with direct tests and a comparative study. Eskişehir Osmangazi University, Graduate School of Natural and Applied Sciences, Ph.D. Thesis, Eskisehir-Turkey, (in Turkish with English abstract).
Van der Merve DH (1964). The prediction of heave from the plasticity index and the percentage clay fraction of soils. Civil. Eng. South Africa, pp.103-107.
Verhoef PNW (1992). The methylene blue adsorption test applied to geomaterials, Memoirs of the centre of Engineering Geology in the Netherlands. Deltf Uviversity of Technology, GEOMAT. 101: 2- 70.
Vijayvergiya VN, Ghazzaly OL (1973). Prediction of swelling potential of natural clays. 3rd Int. Research and Engineering Conference on Expansive Clays, pp. 227-234.
Yukselen Y, Kaya A (2008). Suitability of the methylene blue test for surface area, cation exchange capacity and swell potential determination of clayey soils. Eng. Geol., 102: 38-45.