STATISTICAL ESTIMATION OF THE COMPRESSIBITY OF BAGHDAD COHESIVE SOIL

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ABSTRACT

Because of the time and expense involved in performing consolidation tests, it is often desirable to obtain approximate values of (C_c and C_r) by using other soil properties which are more easily determined. The literature contains numerous equations linking soil compressibility to its physical and index properties. As these equations are often used to obtain preliminary evaluations of (C_c) and (C_r), it is important to know the reliability of these equations.

In this paper an attempt was made to estimate (C_c and C_r) of Baghdad cohesive soil from other soil properties. A number of commonly used empirical correlation equations that have been developed during the last six decades to estimate (C_c and C_r) were compiled and evaluated. The results of routine laboratory tests of a large number of databases of Baghdad soil were correlated with more sophisticated laboratory consolidation results by conducting simple and multiple regression analyses. It was concluded that the compression index of Baghdad cohesive soil cannot be estimated from Atterberg limits and the better values of compression and recompression indices of Baghdad soil can be obtained when more than one index property is used in the regression analysis.

تقييم احصائي لانضغاطية تربة بغداد المتماسكة

الخلاصة

نظرا للوقت والكلفة المتضمنة عند اجراء فحوص الانضمام, فانه من المفضل الحصول على قيم تقريبية لـ (C_c) و (C_r) باستخدام خصائص اخرى للتربة تحدد بطرق اسهل. تضمنت المصادر العديد من المعادلات التي تربط بين انضغاطية التربة والخصائص الفيزياوية والدليلية لها. على الرغم من استخدام هذه المعادلات للحصول على تقييم اولي لـ (C_c) و(C_r) الا ان معرفة مدى ملائمتها المعدلات يعد امرا مهما.

في هذا البحث تم اجراء محاولة لتخمين قيم (C_c) و(C_r) الخاصة بتربة بغداد باستخدام الخائص الاخرى لها. تم جمع وتقييم عدد من المعدلات الوضعية الشائعة الاستخدام عند تخمين قيم (C_c) و(C_r) والتي تم تطويرها خلال العقود الستة الماضية. تم تكوين قاعدة بيانات تتضمن نتائج الفحوص التقليدية لتربة بغداد المتماسكة وتم اجراء ترابط احصائي لهذه النتائج مع فحص الانضمام الاكثر تعقيدا وذلك باستخدام التحليل الاحصائي البسيط والمتعدد. اظهرت نتائج الدراسة عدم امكانية الاعتماد على حدود اتربيرك لتخمين قيم معامل الانضغاط لتربة بغداد, كما بينت النتائج ان استخدام اكثر من صفة دليلية ضمن التحليل الاحصائي يعطي نتائج افضل لقيم (C_c) و(C_r) الخاصة بتربة بغداد.

KEYWORDS: compression index, recompression index, correlation, initial void ratio, natural moisture content, total unit weight, dry unit weights.

INTRODUCTION

The analysis of all geotechnical problems requires the adoption of a soil behavioral model complete with all relevant soil properties. These soil properties are not known beforehand, and therefore the design engineer must either measure the properties under controlled conditions in the laboratory or field or estimate the properties from other test data. These estimates are made most often from laboratory index tests and in-situ test results, which are correlated to soil properties either by calibration studies or by back calculation from full scale load test data obtained in the field.

Comprehensive characterization of the soil at a particular site would require an elaborate and costly testing program, well beyond the scope of most projects budgets. Instead, the design engineer must rely upon more limited soil information, and that is when correlations become most useful, (Kulhawy and Mayne 1990).

There is large number of empirical equations presented in the geotechnical literature for the estimation of compression and/or recompression indices (Skempton, 1944; Helenelund, 1951; Cozzolino, 1961; Sowers, 1970; Wroth and Wood, 1978; Nagaraj and Murthy, 1986; Nakase et al., 1988; Bowles, 1996; Gunduz and Arman, 2007: Ahadiyan et. al., 2008: Isik, 2009).

Bowles 1996, suggested that to identify the published equations, one should start compiling a local database with minor adjustments to the numerical constants, as defining the local soil..

Kulhawy and Mayne 1990 mentioned that caution must always be exercised when using broad, generalized correlation of index parameters with soil properties. The source, extent, and limitation of each correlation should be examined carefully before use to ensure that extrapolation is not being done beyond the original boundary conditions. Local calibrations where available, are to be preferred over the board, generalized correlations.

In addition, many of the common correlations in the literature have been developed from test data on relatively insensitive clays of law to moderate plasticity. Extrapolation of these correlations to special soils should be done with particular care because the correlations do not apply strictly to these soils.

THE OBJECTIVES OF THIS STUDY

It is very important in geotechnical engineering to know the compressibility properties of a soil. Usually compression and/or recompression indices are used for the calculation of consolidation settlement of fine grained soils. They are conventionally determined by laboratory oedometer tests. However, the duration of consolidation tests is very long compared to standard index tests. For this reason, it is important to estimate compression and recompression indices with reasonable accuracy for preliminary calculations and to control the validity of consolidation tests.

Numerous attempts have been made to correlate compressibility with some simple index properties. Giasi, et. al., 2003, stated that the multitude of equations present in the literature indicates that none of them can be assumed to have general validity, but that each of them can be valid within defined ranges.

It is known that the compressibility characteristics of a soil can be correlated to different characteristic properties, such as the liquid limit, the plasticity index, the natural water content, the void ratio, etc. The use of one property rather than another is linked to the kind of soil being considered and to the conditions in which it is analyzed, Giasi, et.. al., 2003.

As such this study will include the following

- Investigation of the soil data generated by soil investigation for different projects in Baghdad city to explore the range of values and variations of (C_c) and (C_r).
- Compiling a local database to identify the local soil.
- Comparing the results of (C_c) and (C_r) obtained from existing proposed relations to those of laboratory measurements.

- Correlating routine laboratory tests results with more sophisticated laboratory results used to determine geotechnical design parameters by conducting simple and multiple regression analysis.

DATABASE COMPILATION AND DESECRIPTION

In order to build the database, a large number of consolidation and physical test results was compiled. These results were generated by soil investigation for different projects in Baghdad city during the last three decades.

Soil parameters used in the database were natural water content (wn), initial void ratio (e_o), total unit weight (γ_t), dry unit weight (γ_d), liquid limit (LL), plastic limit (PL), plasticity index (I_p), effective overburden pressure (Po), compression index (C_c), and recompression index (C_r). In order to assess the adequacy of the database, descriptive statistics of each data set present in the database were determined. **Table 1** presents the descriptive statistics of each variable and **Fig. 1** presents the histogram of the variables.

It should be mentioned that (50.9%) of the values of (C_c) used in the present work are less than (0.2), while (46.6%) of the values ranged from (0.2 to 0.4). Thus, the degree of compressibility of Baghdad cohesive soil, according to Kulhawy and Mayne 1990, can be classified as low to intermediate. The ratio of (C_s/C_c) for Baghdad soil was calculated from the data and found to vary from (0.047 to 0.533). On the other hand, more than (59%) of the (LL) of the samples is less than (50%) which indicated that the predominated consistency of Baghdad clay is Low. Also, the values of the natural water content, in general, are closer to the plastic limit than to liquid limit. This trend suggests that the soil is somewhat heavily overconsolidated. (Bowles, 1996).

According to **Table 1**, it can be concluded that the database consists of a wide range of data. Therefore, this database can be used for the comparison of the performance of existing empirical equations and for the development of new equations. On the other hand, as can be observed from the frequency histograms and from the statistical parameters given in **Table 1**, for most of the soil parameters it appears realistic to assume a normal distribution.

Table 1 summary of statistical parameters

	w_n	LL	PL	PI	γ_t	γ_d	eo	Po	Cc	Cs
No.of values	596	820	817	818	390	386	350	425	328	330
Minimum	2	21	4	3	16.2	11.33	0.411	9.3	0.1	0.01
Maximum	43	83	38	58	21.7	19.71	1.14	430	0.71	0.099
Range	41	62	34	55	5.5	8.377	0.729	420.7	0.61	0.089
Mean	24.5	47.2	23.39	23.8	19.6	15.8	0.708	121.24	0.213	0.045
Median	24	47	23	24	19.6	15.84	0.7	95.6	0.2	0.042
Std. deviation	4.694	10.83	4.726	9.087	0.835	1.107	0.118	83.85	0.069	0.0156
Units	%	%	%	%	kN/m^3	kN/m^3	--	kN/m^2	--	--

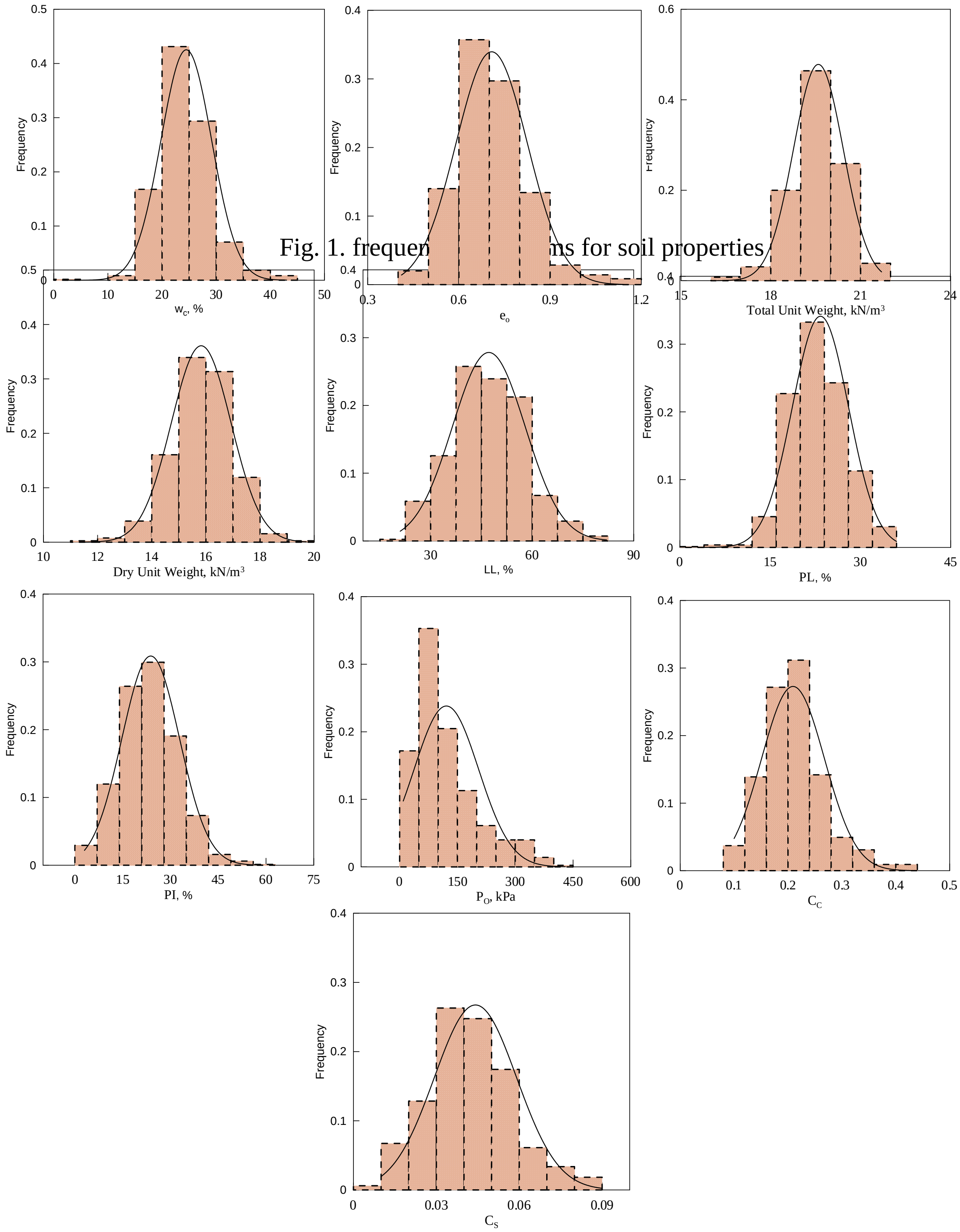

Fig. 1. continued

A COMPENDIUM OF THE EXISTING CORRELATIONS

Over the past six decades, a number of empirical equations have been developed for relating compression and recompression indices to deferent soil properties. Al-Khafaji 2005, stated that the lack of uniformity in data collection and data interpretation makes it difficult to verify the accuracy of derived empirical equations. However, a large number of published equations are now available to warrant a closer look at the validity, accuracy, and usefulness of many available empirical formulas for compression index estimation.

Table 2 and **Fig. 2** summarize the equations correlated between (C_c) and (C_r) with other index properties of soils consisting of (LL), (PI), (w_n), (e_o), (γ_t), and (γ_d). These equations were proposed or established by many different authors from various places, between the years 1944 and 2009.
It should be noted that there have been continuous attempts, right from the early stages (1944), to develop simple methods to predict (C_c) of soils from simple soil index parameters. In contrast to (Cc), only few empirical equations were developed for the estimation of (C_r), were such attempts started latterly after (1980).
Nevertheless, one may observe that the correlation equations vary one with another, with some indicating great differences and some being non linear. Also, some of these correlations are supposed to reflect compression index of all soils while others are limited to specific soil types and/or geographic location.
Djoenaidi, 1985, and Lav, and Ansal 2001, mentioned that the differences in the correlation equations may be attributed to the use of different data sources from which those equations were established. Using linear correlation, as stated by Djoenaidi 1985, indicated that the (C_c) can be forecast as a linear function of the index properties. However, in practice, care should be taken in selecting or using the existing correlations for a given soil, because most of these correlations are applicable only to certain regions.
To examine the applicability of the correlation equations summarized in **Table 2** to Baghdad cohesive soils, these relationships are plotted in **Fig. 2** in which (C_c) and (C_r) of Baghdad Soil are plotted against (LL), (PI), (w_n), (e_o), (γ_t), and (γ_d) successively. The following statements can be made based on **Table 2** and **Fig. 2**:

- These relationships indicated the same trend, i.e, the greater (LL), (PI), (w_n), and (e_o) or the lesser (γ_t), and (γ_d), gives the higher the (C_c) and (C_r).
- Although there is considerable scatter, most of the lines agree fairly well.
- Because the compression settlement depends on the initial in situ void ratio (e_o), it is probably better to use these equations that include (e_o) either directly or indirectly, (Bowels, 1996).
- It can clearly be observed that the correlation equations using one independent variable might not satisfy the compressibility of Baghdad cohesive soil for the given range of data.
- Correlation equations using more than one independent index property, like equations (F7 or F9) in **Table 2**, seem to be better to provide the best reliability.

However, attention should be given to the conditions in which the correlation had been made and the statistical accuracy of the equations, before choosing a single empirical equation for a particular type of soil.

Table 2 summary of empirical equations developed for relating C_r or C_c

	Equation	Notes	Reference
		C_r or C_c = f(LL)	
A1	$C_c = 0.007 (LL - 10)$	Remolded clays	Skempton (1944)
A2	$C_c = 0.0046 (LL – 9)$	Brazilian clays	Cozzolino (1961)
A3	$C_c = 0.009(LL - 10)$	N.C. Clays of moderate sensitivity	Terzaghi and Peck (1967)
A4	$C_c = 0.006 (LL - 9)$	Clay from Greece and some parts of USA	Azzouz et al. (1976)
A5	$C_c = (LL - 9)/109$	All clays	Mayne (1980)
A6	$C_c = 0.00234 LL G_s$	All inorganic clays	Nagaraj and Srinivasa Murthy(1985, 1986)
A7	C_c=0.009 LL + 0.035	$R^2 = 0.705$	Ferreira and Ladeira (1995)
A8	$C_c = 0.006 (LL + 1)$	All soil ($R^2 = 0. 259$)	Lav and Ansal (2001)
A9	C_c= 0.009 (LL - 16)	For (16< LL < 200)	Al-Khafaji (2005)
A10	$C_r = 0.000463 LL G_s$	-	Nagaraj and Srinivasa Murthy(1985)
A11	$C_r = 0.0007 LL + 0.0062$	42 test data, Turkey	Isik (2009)

C_r or C_c = f(I_p)			
B1	$C_c = 0.005\ I_p\ G_s$	All remolded normally consolidated clays	Wroth and Wood (1978)
B2	$C_c = 0.046 + 0.0140\ I_p$	For $I_p < 50$	Nakase et al. (1988)
B3	$C_c = I_p/74$	Data from different soils	Kulhawy and Mayne (1990)
B4	$C_c = 0.011\ (I_p - 5.7)$	For cohesive soil (R^2=0.79)	Heng (2006)
B5	$C_r = 0.00194\ (I_p - 4.6)$	Best for $I_p < 50\%$	Nakase et al. (1988)
B6	$C_r = I_p/370$	Data from different soils	Kulhawy and Mayne (1990)
C_r or C_c = f(w_n)			
C1	$C_c = 0.85\ (w_n/100)^{1.5}$	Finnish mud and clay	Helenelund (1951)
C2	$C_c = 0.01(w_n - 5)$	Clay from Greece and some parts of USA	Azzous et al., (1976)
C3	$C_c = 0.01\ w_n$	Canada	Koppula (1981)
C4	$C_c = 0.01(w_n - 7.549)$	Soil from 9 sites in USA	Rendon-Herrero (1983)
C5	$C_c = 0.0115\ w_n$	Organic silts and clays	Bowles (1984)
C6	$C_c = 0.015\ (w_n - 8)$	Cohesive soil in Taiwan	Moh et. al. (1989)
C7	$C_c = 0.01\ w_n - 0.042$	R^2 = 0.856	Ferreira and Ladeira (1995)
C8	$\ln C_c = 1.235 \ln w_n - 5.65$	All soil (R^2=0.54)	Lav and Ansal (2001)
C9	$C_c = 0.00454\ (w_n - 10)$	soft soils in southern Germany	Kempfert Gebreselassie (2006)
C10	$C_r = 0.0133\ e^{0.036.wn}$	42 test data, Turkey	Isik (2009)
C_r or C_c = f(e_o)			
D1	$C_c = 1.15(e_o - 0.35)$	All clays	Nishida (1956)
D2	$C_c = 0.29\ (e_o - 0.27)$	Inorganic silty clays	Hough (1957)
D3	$C_c = 0.43\ (e_o - 0.25)$	Brazilian clays	Cozzolino (1961)
D4	$C_c = 0.75\ (e_o - 0.50)$	Soil with low plasticity	Sowers, (1970)
D5	$C_c = 0.40\ (e_o - 0.25)$	Clay from Greece and some parts of USA	Azzous et al., (1976)
D6	$C_c = 0.141\ G_s^{1.2}\ [(1+e_o)/G_s]^{2.38}$	Soil from 9 sites in USA	Herrero (1980)
D7	$C_c = 0.5\ ((1+e_o)/G_s)^{2.4}$	-	Oswald (1980)
D8	$C_c = 0.54\ (e_o - 0.23)$	Taiwan clay	Moh et. al. (1989)
D9	$C_c = 0.379\ e_n - 0.046$	R^2 = 0.855	Ferreira and Ladeira (1995)
D10	$C_c = 0.61\ e_o - 0.17$	-	Tan and Gue (2000)
D11	$\ln C_c = 1.272 \ln e_0 - 1.282$	All soil (R=0.817)	Lav and Ansal (2001)
D12	$C_c = 1.02 - 0.95\ e_o$	For overconsolidated low plasticity clay	Gunduz and Arman (2007)
D13	$C_c = 0.287\ e_o - 0.015$	Ahwaz Soil (R2 = 0.47)	Ahadiyan et. al. (2008)
D14	$C_c = 0.3\ (e_o - 0.27)$	Soils in Southeastern Wisconsin.	Edilm and Benson (2009)
D15	$C_r = 0.0121\ e^{1.3131\ eo}$	R^2 = 0.6501	Isik (2009)
C_r or C_c = f(γ_d or γ_n)			
E1	$C_c = 0.5\ (\gamma_w / \gamma_d)^{2.4}$	Soil of all types	Cited in Kempfert Gebreselassie (2006)
E2	$C_r = 9.3158\ e^{-2.8048\ \gamma n}$	42 test data, Turkey, (γ_d is t/m^3)	Isik (2009)
E3	$C_r = 0.1257\ \gamma_d^{-2.8826}$	42 test data, Turkey, (γ_d is t/m^3)	Isik (2009)
C_r or C_c = f(Different Variables)			
F1	$C_c = 0.37(e_o + 0.003LL + 0.0004w_n - 0.34)$	Clay from Greece and some parts of USA	Azzouz et al. (1976)
F2	$C_c = 0.141\ G_s\ (\gamma_{sat} / \gamma_d)^{2.4}$	Clay from Greece and some parts of USA	Rendon-Herrero (1983)

F3	C_c=0.37(e_o + 0.003 LL - 0.34)	R^2 = 0.86	Bowles (1984)
F4	C_c = 0.009 w_n + 0.005 LL	All clays	Koppula (1986)
F5	C_c = -0.156 + 0.41I e_o + 0.00058 LL	72 data points	Al-Khafaji and Andersland (1992)
F6	C_c= -0.048+ 0.005w_n+0.179 e_n	Soil from Aveiro in Portugal	Ferreira and Ladeira (1995)
F7	C_c = (0.001 w_n + 0.114) (1+e_o)	For alluvial soils	Crumley, et. al. (2003)
F8	C_c= -0.023 + 0.001 LL + 0.271e_o	R^2 = 0.48	Ahadiyan et. al. (2008)
F9	C_r = 0.037-0.00032 w_n -0.0273 γ_d +0.064 e_o	42 test data, Turkey (γ_d is t/m^3)	Isik (2009)

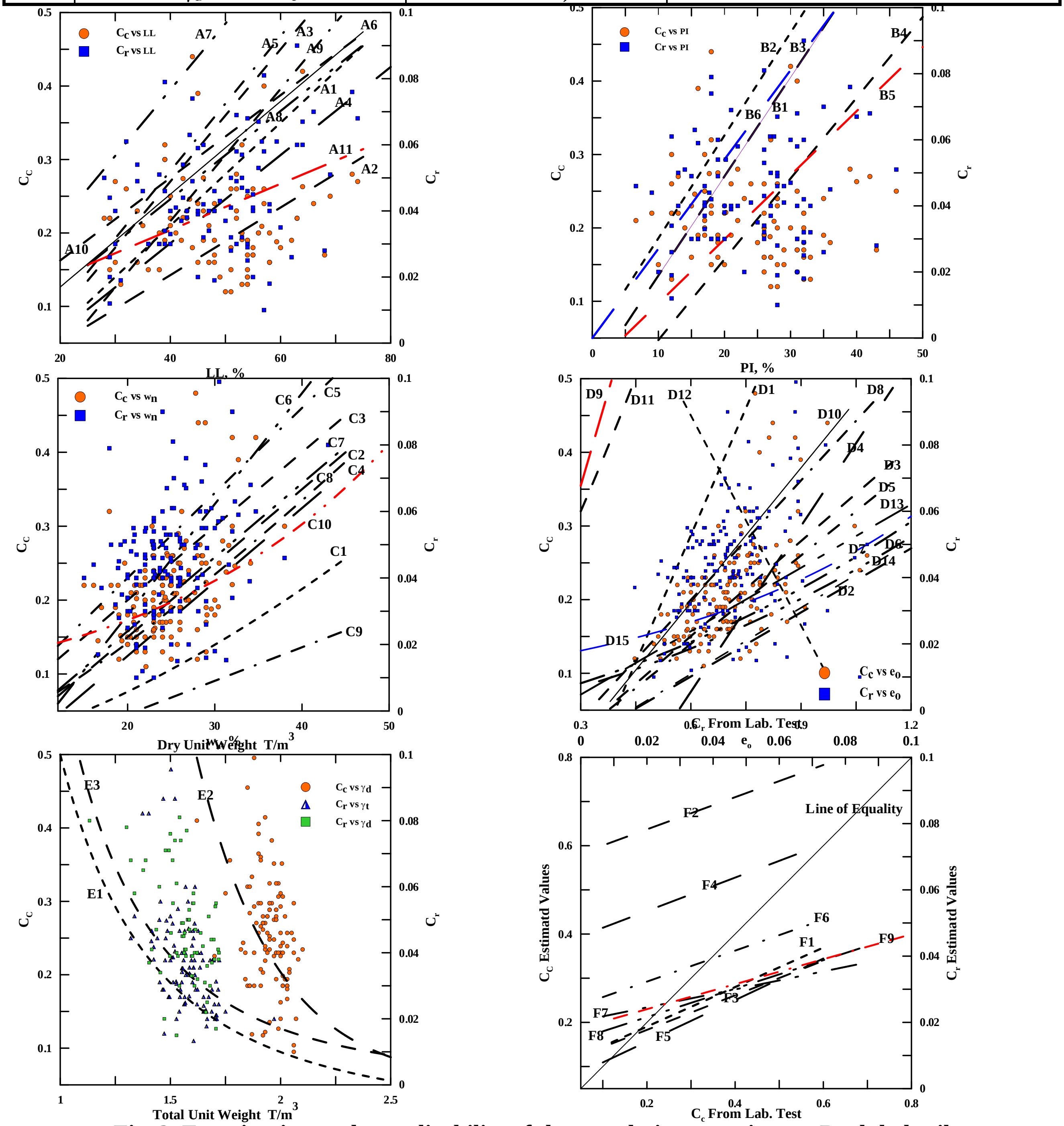

Fig. 2. Examination to the applicability of the correlation equations to Baghdad soil

SIMPLE AND MULTIPLE REGRESSION ANALYSIS OF (C_c) and (C_r)

To examine whenever the (C_c) and (C_r) of Baghdad cohesive soil can be predicted from the knowledge of other soil properties, regression analysis was performed using the database compiled in this paper. Simple and multiple regression analysis were carried out using a computer program (SPSS).
In order to observe the improvement in the correlations developed due to the adopted parameters, the correlation coefficient (R) matrices for the whole data should be establish. Lav and Ansal 2001, stated that a lower limit of ($R \geq \pm 0.5$) can adopted for developing various regression models. Accordingly, a correlation coefficient (R) with values greater than or equal to ($\pm$ 0.5) was adopted in the present regression models.

Simple regression analysis was performed between the (C_c) and (C_r) and the selected soil properties. The (C_c) and (C_r) are dependent variables and are treated as functions of natural water content (w_n), initial void ratio (e_o), total unit weight (γ_t), dry unit weight (γ_d), liquid limit (LL), plastic limit (PL), plasticity index (I_p), and effective overburden pressure (P_o) which are termed as independent variables. The resulting (R) values for all cases adopted in the simple analysis are shown in **Table 3.**

Table 3 Simple regression analysis performed to estimate (C_c) and (C_r).

Independent Variables	Correlation Coefficient (R)					
	Linear Regression		Curve Estimation			
	C_c	C_r	C_c	Model	C_r	Model
w_o	0.460	0.402	0.475	Cubic	0.399	Cubic
e_o	0.570	0.420	0.591	Cubic	0.448	Cubic
γ_t	0.452	0.374	0.454	Exponential	0.373	Logarithmic
γ_d	0.528	0.451	0.530	Logarithmic	0.452	Logarithmic
LL	0.114	0.356	0.189	Cubic	0.389	Cubic
PL	0.260	0.355	0.266	Power	0.355	Cubic
PI	0.000	0.441	0.084	Cubic	0.442	Power
P_o	0.621	0.336	0.621	Cubic	0.374	Cubic

Values of the coefficient of correlation ($R<0.5$) shown in **Table 3** indicate that direct correlation between (C_r) and other soil properties are rather poor when applied to a large number of data from Baghdad cohesive soil. Unlike what has been observed for (C_r), the statistical significance of the direct correlations between (C_c) and (e_o),(γ_d), and (P_o) , where ($R \geq \pm 0.5$), are moderate. As can be observed in this table, the Atterberg limits and the natural water content have a low correlation coefficient value for all cases considered in evaluating the (C_c) and (C_r).
Giasi et. el. 2003, mentioned that the compressibility characteristics of a soil can be correlated to different characteristic properties, and the use of one property rather than another is linked to the kind of soil being considered and to the conditions in which it is analyzed. Finally he stated that the Atterberg limits can be used to evaluate the compression index of remoulded soils samples. It can be concluded that the correlation equations using Atterberg limits in a simple regression correlation might not satisfy the compressibility of Baghdad cohesive soil for the given range of data**.**
Curve estimation using models shown in **Table 3** were performed and the related correlation coefficients were calculated to investigate the effect of these models on the value of (R). It was observed that, in most cases, no significant increase in the value of the correlation coefficient was obtained when the curve estimation is used in the regression analysis**.**
On the other hand, multiple linear regression studies were conducted to express (C_c) and (C_r) in terms of the aforementioned database for Baghdad soil. In this analysis, the emphasis is on the soil properties which have a reasonable value of (R) obtained in the simple analysis, i.e. (e_o), (γ_d), and

(P_o). The results of the multiple analyses between (C_c) and (C_r) and other soil properties are shown in **Table 4**. An examination to this table reveals that introducing Atterberg limits conjugated with other parameters reduced the coefficient of correlation in many cases. Nevertheless, in comparison with the results from simple linear regression analysis, the inclusion of more than one independent variable statistically improves the relationships. The best improvement in the value of (R) can be reached when (w_o) or (γ_t) or (γ_d) are included in addition to (e_o) and (P_o) in multiple regression analysis.

Table 4 Multiple regression analysis performed to estimate (C_c) and (C_r)

Independent Variables			Correlation Coefficient (R)	
			Dependent Variables	
1	2	3	C_c	C_r
e_o	LL	-	0.551	0.452
e_o	PL	-	0.560	0.422
e_o	PI	-	0.549	0.398
e_o	w_o	-	0.595	0.460
e_o	w_o	γ_t	0.649	0.552
e_o	w_o	γ_d	0.649	0.552
e_o	w_o	P_o	0.752	0.571
e_o	γ_t	-	0.642	0.532
e_o	γ_t	γ_d	0.648	0.552
e_o	γ_t	P_o	0.782	0.567
e_o	γ_d	-	0.648	0.551
e_o	γ_d	P_o	0.782	0.577
e_o	P_o	-	0.757	0.557
γ_d	LL	-	0.447	0.531
γ_d	PL	-	0.492	0.543
γ_d	PI	-	0.444	0.455
γ_d	w_o	-	0.533	0.457
γ_d	w_o	γ_t	0.541	0.461
γ_d	w_o	P_o	0.692	0.486
γ_d	γ_t	-	0.530	0.455
γ_d	γ_t	P_o	0.692	0.485
P_o	LL	-	0.652	0.495
P_o	PL	-	0.670	0.487
P_o	PI	-	0.644	0.403
P_o	w_o	-	0.658	0.460
P_o	w_o	γ_t	0.692	0.486
P_o	γ_t	-	0.679	0.445

A list of possible relationships for estimating the (C_c) and (C_r) using various index parameters developed in this study is summarized in **Tables 5 and 6**. During this study, all possible relationships were tried; however, naturally in some of these relationships, the correlation coefficients were low. The equations given in these tables are the ones which had the highest correlation coefficient ($R \geq \pm 0.5$).

Table 5 Summary of relationships developed to evaluate (C_r).

Relationships Developed to Evaluate (C_r)		
Independent Variables	(R)	Regression Equation
e_o, w_o, γ_t	0.552	C_r= 0.017 + 0.061 e_o + 0.0004 w_o – 0.001 γ_t
e_o, w_o, γ_d	0.552	C_r= 0.02 + 0.061 e_o + 0.00023 w_o – 0.001 γ_d
e_o, w_o , P_o	0.571	C_c= -0.009 + 0.061 e_o + 0.0004 w_o + 0.00003 P_o
e_o, γ_t , P_o	0.567	C_r= 0.0178 + 0.0622 e_o - 0.0011 γ_t + 0.00004 P_o
e_o, γ_d	0.551	C_r= 0.038 + 0.068 e_o - 0.002 γ_d
e_o, γ_d , P_o	0.577	C_r= 0.0196 + 0.0614 e_o - 0.00134 γ_d + 0.00003 P_o
e_o, P_o	0.557	C_r= -0.005 + 0.067 e_o + 0.00004 P_o

Table 6 Summary of relationships developed to evaluate (C_c).

Relationships Developed to Evaluate (C_c)		
Independent Variables	(R)	Regression Equation
e_o	0.570	C_c=0.31 e_o - 0.006
e_o	0.591	C_c=0.620 - 2.42 e_o + 3.84 $(e_o)^2$ – 1.74 $(e_o)^3$
P_o	0.621	C_c= 0.159 + 0.0005 P_o
e_o, w_o	0.590	C_c= -0.034 + 0.25 e_o + 0.003 w_o
e_o, w_o, γ_d	0.649	C_c= 0.113+ 0.31 e_o + 0.001 w_o – 0.009 γ_d
e_o, w_o, γ_t	0.649	C_c= 0.103+ 0.308 e_o + 0.002 w_o – 0.008 γ_t
e_o, w_o , P_o	0.752	C_c= -0.02 + 0.274 e_o + 0.00008 w_o + 0.0004 P_o
e_o, γ_t	0.642	C_c= 0.2 + 0.345 e_o - 0.012 γ_t
e_o, γ_t , P_o	0.782	C_c= -0.003 + 0.298 e_o + 0.0018 γ_t + 0.0004 P_o
e_o, γ_d	0.648	C_c= 0.19 + 0.313 e_o - 0.012 γ_d
e_o, γ_d , P_o	0.782	C_c= -0.0405 + 0.3018 e_o + 0.0001 γ_d + 0.00044 P_o
γ_d, γ_t , P_o	0.692	C_c= 0.463 - 0.019 γ_d + 0.0001 γ_t + 0.0005 P_o
e_o, P_o	0.757	C_c= -0.021 + 0.278 e_o + 0.00042 P_o

A comparison between the relationships proposed by various authors that are shown in **Table 2** and the ones developed in this study is conducted. It is very interesting that the relationship proposed to calculate the compression index in terms of void ratio of Baghdad soil from the simple linear analysis is exactly the same as the relationship developed by Ahadiyan et. al. 2008 for Ahwaz Soil (D13 in **Table 2**). Also, one can notice that the relationship proposed to predict the (C_c) of Baghdad soil as a function to void ratio and water content (multiple analysis) is similar to equation (F6) shown in Table 2 and suggested by Ferreira and Ladeira 1995 for Soil from Aveiro Portugal. Moreover, equation (F9) shown in Table 2 proposed by Isik 2009 to estimate the recompression index of the Turkish soils is like that developed in this study from multiple analysis to void ratio, water content, and dry unit weight.

Finally, it appears from the study conducted that initial void ratio, dry unit weight, and effective overburden pressure yielded sufficiently reliable correlation to estimate recompression index of Baghdad cohesive soil. Also, a good estimation was obtained for compression index of Baghdad cohesive soil from multiple analyses of initial void ratio, dry unit weight, and effective overburden pressure.

CONCLUSIONS:

A database consisting of large numbers of data sets containing consolidation and physical properties test results obtained during the last years from different parts of Baghdad city was compiled, identified, and used to conduct a statistical study to determine suitable correlations for estimating compression and recompression indices. A number of commonly used empirical correlation equations that have been developed during the last six decades to estimate (C_c and C_r) were summarized and evaluated. A simple and multiple regression analysis were adopted and a parametric study was carried out in order to obtain the most suitable and practically applicable relationships.

The main conclusions of the present study are as follow:

- The evaluation of the database indicates that the degree of compressibility of Baghdad cohesive soil can be classified as low to intermediate. While the ratio of (C_s/C_c) for Baghdad soil varies from (0.047 to 0.533).
- The examination of the commonly used empirical correlation equations shows that no one of existing simple empirical correlation equations given by different researchers is valid to estimate the recompression indices of Baghdad cohesive soil.
- The results of regression analysis conducted in this study reveal that the compression index of Baghdad cohesive soil cannot be estimated from Atterberg limits and the better values of compression and recompression indices of Baghdad soil can be obtained when more than one index property is used in the regression analysis.
- Finally, in practice, care should be taken in selecting or using the existing correlations for a given soil, because most of these correlations are applicable only to certain regions.

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NOMENCLATURE:

e : void ratio

e_o: natural void ratio

LL: liquid limit

I_p : plasticity index

P : consolidation pressure

PL: plastic limit

P_o : effective overburden pressure

R : Correlation Coefficient

w_o: natural moisture content

γ_d :dry unit weight

γ_t: total unit weight