New Correlation of Compression Index from Consistency Index of Cohesive Soils

Soumi Dey[1] and Bikash Chandra Chattopadhay [2]
[1]*Post-graduate student, Meghnad Saha Institute of Technology, Kolkata, West Bengal*
[2]*Professor, Department of Civil Engineering, Meghnad Saha Institute of Technology, Kolkata*
Civil Engineering Department, Bengal Engineering Science University, West Bengal

***Abstract* - Evaluation of time dependent settlement of foundations of structure assumes great importance when zone of influence due to new construction consists of cohesive material below water table. Estimation is generally made on the basis of consolidation test on undisturbed soil samples collected from such cohesive soil at the site. Collection of such sample is difficult, time consuming and costly and testing of such soil sample is also time consuming and costly. At any point of time only limited number of such test could be performed at a testing laboratory and only limited number of such test are generally done. Soils being erratic in nature, generally limited number of consolidation test may not be sufficient to provide information of consolidation characteristics in horizontal and vertical direction at the site. As a result efforts had been made to predict compression index from simple soil properties which could be done quickly at low cost and time from representative samples. More than fifty such correlations are available but such correlations do not predict values with reasonable accuracy. In this paper a correlation dependant on multi-number influencing factor is presented and the prediction from this method gives encouraging results when compared with experimental values of compression index.**

***Index Terms* - Compression index, Consolidation settlement, Correlation, Consistency index.**

I.INTRODUCTION

For cost effective and safe construction of foundations at sites having deposits of fine-grained soils within the zone of influence due to new construction, evaluation of consolidation settlement assumes great importance. The compression index (Cc) of the affected soils within the zone of influence needs to be known for such evaluations. Estimation of the compression index are made generally on the basis of results of consolidation test made on undisturbed soil samples, collected from specified depths at the site. Collection of such soil samples require high cost and complex sampling devices, which again require high skill for the operator, proper maintenance of the sampling device and long time for operation. As a result such procedures are adopted only in limited cases, particularly when samples are to be collected below water table. The degree of disturbances caused during sampling, transportation from field to laboratory and preparation of samples for test, are also unknown. Again consolidation tests require large time to give result, and only limited number of tests can be performed in most of the testing laboratories at any point of time. Further the soils in general and alluvial soils in particular are very erratic and only limited number of borings in the field and corresponding limited number of consolidation tests may not provide sufficient information to the designers for mapping variation in consolidation characteristics of the soils at sites both in horizontal and vertical directions.

As a result from very early days, efforts had been made to predict the value of compression index of fine grained soils from Atterberg's limits of liquid limit (LL) and plastic limit (PL) of the soil, which can be done quickly at low cost and time on representative soil samples, collected during field exploration (Skempton(1944), Terzaghi et al (1948)). Over the past, many correlations for predicting the value of compression index of cohesive soils on the basis of simple properties of the soils, had been presented. Search for such correlations over so long period is for developing reliable correlation applicable to foundation engineering for design.

II. BRIEF REVIEW OF LITARATURE

Large number of correlations for compression index (Cc) of cohesive soils from different simple soil properties, had been presented by researchers over last eight decades. Those correlations relate the compression index (Cc) with properties like liquid limit (LL), initial void ratio (eo), void ratio at liquid limit (eL), specific gravity of soil solids (Gs), natural moisture content (wn) and plasticity index (PI). The available correlations maybe classified with relation to

1. Liquid limit (LL)
2. Void ratio at liquid limit (eL)
3. Liquid limit (LL) at initial void ration (eo)
4. Plasticity index (PI)
5. Initial void ratio (eo)
6. Natural moisture content (wn) respectively.

Accordingly such correlations are tabulated in Table 1 below, indicating applicability and references of such relations.

Table-1: Different correlations for compression index (Cc) with different soil properties.

SL. No	Correlation	Applicability	Reference
i. Correlations of Compression Index (C_c) related to Liquid Limit (LL):			
1	$C_c = 0.007$ (LL – 10)	Remolded cohesive soils	Skempton(1944)
2	$C_c = 0.01$ (LL–12)	Osaka alluvial clays	Murayama et al. (1958)
3	$C_C = 0.013$ (LL–13.5)	All clays	Yamagutshi (1959)
4	$C_c = 0.013$ LL	Ariake clay	Kyushu Branch of JSSMFE (1959)
5	$C_c = 0.014$ (LL–20)	Ishikari clay	Taniguchi et al. (1960)
6	$C_c = 0.0046$ (LL–9)	Brazilian clays	Cozzolino (1961)
7	$C_c = 0.004$ (LL–10)	Rumoi clay	Taniguchi (1962)
8	$C_c = 0.017$ (LL–20)	All clays	Shouka (1964)
9	$C_c = 0.009$(LL – 10)	Undisturbed clay of medium or low sensitivity	Terzaghi and Peck (1967)
10	$C_c = 0.006$ (LL–9)	All clays with LL< 100%	Azzouz et al. (1976)
11	$C_c = 0.015$ (LL-19)	All clays	Ogawa (1978)
12	C_c = (LL–13)/109	Soil (with LL<100%)	Mayne (1980)
13	$C_c = 0.0063$ (LL–10)	Egyptian clay	Abdrabbo and Mahmoud (1990)
14	$C_c = 0.01$ LL–0.063	Natural soils (cohesive)	Hirata et al. (1990)
ii. Correlations of Compression Index (C_c) related to Initial Void Ratio at Liquid Limit (e_L):			
15	$C_c = 0.2237\ e_L$	Various clays	Nagaraj and Murthy (1983)
16	$C_c = 0.2343\ e_L$	All remoulded normally consolidated clays	Nagaraj et al. (1985)
17	$C_c = 0.274\ e_L$	Various clays	Nagaraj et al. (1995)
iii. Correlations of Compression Index (C_c) related to Liquid Limit (LL) and Initial Void Ratio (e_o):			
18	$C_c = 1.21 + 0.0072$ (LL - 95) + 0.53 (e_0 -1.87)	Soft clay and silts	Cozzolino (1961)
19	$C_c = 0.256 + 0.00106$ (LL - 65) + 0.32(e_0 - 0.84)	Heavy and medium clay and silts	Cozzolino (1961)
20	$C_c = 0.21\ e_o$ +0.00341 LL - 0.07	Various clays	Sengupta (1974)
21	$C_c = 0.37$ (e_0 + 0.003 LL + 0.004)	Various clays	Bowels (1982)
iv. Correlations of Compression Index (C_c) related to Plasticity Index (PI):			
22	$C_c = 0.02 + 0.014$ PI	North Atlantic clay	Nacci et al.(1975)
23	$C_c = 0.5$ PI G_S	Various Clays	Wroth and Wood (1978)
24	$C_c = 1.325$ PI	Remoulding clays	Wroth et al. (1978)
25	$C_c = 1.325$ PI	Remoulding clays	Koppula (1981)
26	$C_c = 0.014$ (PI + 3.6)	Remoulding clays	Sridharan and Nagaraj (2000)
27	$C_c = 0.015$ PI - 0.0198	Various Clays	Nath and Dedalal (2004)
28	$C_c = 0.0082$ PI + 0.0475	Alluvial Soil	Jain et al. (2015)
v. Correlations of Compression Index (C_c) related to Initial Void Ratio (e_o):			
29	$C_c = 0.54$ (e_o - 0.35)	Undisturbed clays	Nishida (1956)
30	$C_c = 0.29$ (e_o - 0.027)	Inorganic silty clay	Hough (1957)
31	$C_c = 0.4049$ (e_o - 0.3216)	Cohesive soil,silt,cla,silty clay and inorganic soil	Hough (1957)
32	$C_c = 0.35$ (e_o - 0.5)	Organic soils	Hough (1957)
33	$C_c = 0.43$ (e_o - 0.25)	Brazilian clay	Cozzolino(1961)
34	$C_c = 0.246 + 0.43$ (e_o - 0.25)	Motley clays of Sao Paulo, Brazil	Cozzolino (1961)
35	$C_c = 1.21+ 1.055$ (e_o - 1.87)	Low lands of Santos, Brazil	Cozzolino (1961)
36	$C_c = 0.50$ (e_o - 0.5)	Undisturbed clays	Serajuddin (1969)
37	$C_c = 0.75$ (e_o - 0.5)	Low plasticity soil	Sowers (1970)
38	$C_c = 0.4$ (e_o - 0.25)	Clays , USA and Greece	Azzouz (1976)
39	$C_c = 0.30$ (e_o - 0.27)	America's clay	Rendon- Herrero (1980)
40	$C_c = 0.33$ (e_o - 0.35)	Undisturbed Clays	Amin et al.(1987)
41	$C_c = 0.208\ e_o + 0.0083$	Chicago clays	Bowles (1989)
42	$C_c = 0.156\ e_o + 0.0107$	All clays, (Moderately Over consolidated)	Bowles (1989)
43	$C_c = 0.42$ (e_o - 0.5)	Egyptian clays with 0.6< e0<2.0.	Abdrabbo and Mahmoud (1990)
44	$C_c = n_0/(371.747-4.275n_o)$	Various clays	Park and Koumoto (2004)
vi. Correlations of Compression Index (C_c) related to Natural Moisture Content (w_n).			
45	$C_c = 0.0102$ (w_n - 9.15)	Cohesive soil,silt,cla,silty clay and inorganic soil	Hough (1957)
46	$C_c = 0.01$ (w_n - 5)	All type of clay	Azzouz et al. (1976)
47	$C_c = 0.01\ w_n$	All type of clay	Koppula (1981)
48	$C_c = 0.01$(w_n - 7.549)	All type of clay	Herrero (1983)
49	$C_c = 0.0102$ (w_n - 9.15)	Alluvial clay and silt in Bangladesh	Serajjudin (1987)
50	$C_c = 0.0115\ w_n$	Organic silt and clays	Bowles (1989)
51	$C_c = 0.0066\ w_n$	Egyptian clays with 20% < wn < 140%.	Abdrabbo and Mahmoud (1990)
52	$C_c = 0.0103\ w_n$	Various clays	Nagaraj (2001)

III. VALIDITY OF AVAILABLE CORRELATIONS

It is observed from table-1, that fifty two correlations for compression index from simple soil properties, had been presented over last eight decades, Development of such a large number correlations over such a long time, indicate the need for finding a reliable correlations with universal applicability in geotechnical engineering field. Otherwise also, for practicing geotechnical engineers, it becomes imperative to identify the suitable one for which predicted value from chosen correlations, compares well with experimental value for reasonable accuracy. Satyanarayana and Reddy (2009) studied the validity of available such correlations for marine soils. They concluded that existing correlations based on influencing factor like liquid limit (LL), initial void ratio (eo) or initial moisture content (wn), are not valid for marine soils. Dey and Chattopadhay (2021) presented a study for checking up the applicability of available correlations in alluvial cohesive soils, around Kolkata in India on either sides of the river Hooghly. The experimental values of compression index from consolidation tests on undisturbed cohesive soils collected from different location at various depths, were compared with the predicted values from different available correlations. Similar conclusion as made by Satyanarayan and Reddy (2009) in marine soils, was observed also for alluvial soils around Kolkata. The work highlighted the need for establishing a reliable correlation for practical use in design.

IV. DEVELOPMENT FOR NEW CORRELATION

Atterberg's work (1911) established that cohesive soils exhibit the existence of unique water content at which the soil changes its state from liquid condition to plastic one (liquid limit, LL) and from plastic state to semi solid one (Plastic limit, PL), and difference between LL and PL is referred as Plasticity index (PI). These unique values of LL and PL for cohesive soils are used for identification and classification of the soil universally. However LL and PL of a fine grained soil help to identify the soil, but engineering behavior of the soil must be also dependent on the existing water content (wn) of the soil. These three important governing factors of the fine grained soil can be combined together in the form of consistency index (Ic), defined as, Ic = (LL-Wn)/(LL-PL)

When Ic is zero, the soil is having its water content at liquid limit and when Ic is one, soil is having its water content at PL. The changes in water content allows to vary from following states:- liquid, very soft, soft, stiff, very stiff, and hard (Terzaghi 1926). Consistency index of cohesive soils is an important factor to define ideal state of a cohesive material to act as a suitable support system. For cohesive material, deformation response under loading seems to be dependent on the initial value of consistency index (Daniela et al 2019). As the existing empirical correlations failed in consistent estimation of compression index value, there is need for establishing more reliable correlation correlating key compressibility parameters (Satyanarayan and Reddy 2009). In view of above, an attempt was made to identify the relationship between compression under of cohesive soils, determined experimentally from 1D consolidation test on undisturbed soil specimen from different locations and the consistency index of the corresponding soil.

For this purpose, large numbers of results of consolidation tests along with values of liquid limit, plastic limit, natural water content etc were collected from different soil investigation reports for construction project around Kolkata on both sides of river Hooghly, in West Bengal, India. These data are presented elsewhere (Dey and Chattopadhyay 2021).For each soil sample, consistency index (Ic) was calculated. The experimental values of compression index (Cc) are plotted against the corresponding consistency index in Fig 1.

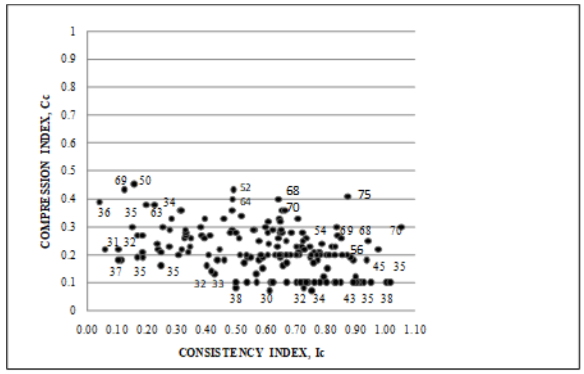

Fig-1: Variation of compression index (Cc) of soils against consistency index (Ic) of the soil.

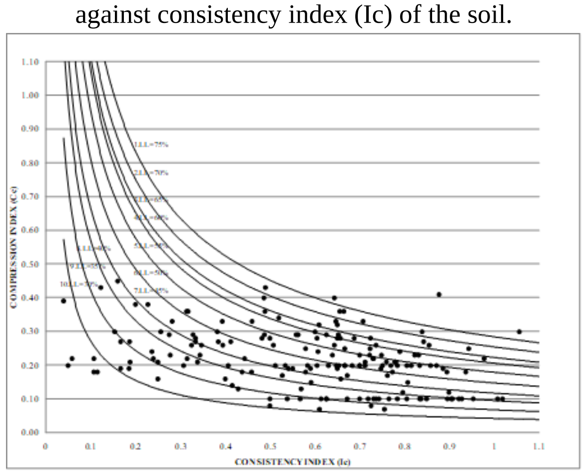

Fig-2: Compression index (Cc) vs. Consistency Index (Ic) for different values of liquid limit.

Examining Fig-1, no simple relation between compression index (Cc) and consistency index (Ic) can be observed. But it is to be remembered that each plotted point giving relation between Cc and Ic is for a particular liquid limit of the soil. If point relating Cc and Ic for same liquid limit value, are joined together, a definite family of curves become distinct. These curves are shown in fig-2 for different values of liquid limit of 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, and 75%. From these cures it is seen that for any liquid limit (LL) of a soil, as Ic increase from 0 to 1, Cc value decrease in a nonlinear way to a constant value gradually. This is true for any value of liquid limit. When Ic is close to nil, the soil is having natural water content very near to its liquid limit and will be highly compressible and will have high value of Cc. It is off course to be noted that for soil having natural water content nearing liquid limit, soil is very soft and it will be extremely difficult to run the consolidation test correctly and experimental value of Cc at that condition may be quite erroneous due to handling error. When initial natural water content of the soil approaches plastic limit of the soil, then the soil will be stiff and Cc value will gradually decrease from that at natural water content near liquid limit.

Further a soil having large value of LL compared to another one having lower liquid limit will exhibit larger value of Cc for same consistency index compared to the later.

In nature it is to be farther noted that cohesive soils exhibit wider variation in the value of their liquid limit, compared to their plastic limits which show much closer range of value (Table-2).

Table-2: Liquid limits and Plastic limits parameters for different clay forming minerals. (After Lambe and Whitman (1969) and Mitchell (1993)).

Clay mineral type	Liquid limit (%)	Plastic limit (%)
Montmorillonite	100–900	50–100
Nontronite	37–72	19–27
Illite	60–120	35–60
Kaolinite	30–110	25–40
Hydrated halloysite	50–70	47–60
Dehydrated halloysite	33–55	30–45
Attapulgite	44–47	36–40
Chlorite	200–250	130–140

As a result, in nature as consistency index approaches-1 , natural moisture content of the most of the soils approaches the plastic limit in a close range and as a result compression index (C_c) also approach value in a close range. Reverse is the case when consistency index approach a nil value when natural water content became nearer to liquid limit of the soil, varying widely in nature, and as a result compression index (C_c) also varies in very wide range, depending on the value of liquid limit.

The experimental relationship between compression index, (C_c) and consistency index (I_c), for different values of liquid limit (LL) of the soil, shown in Fig-2, may be expressed as

$$C_c = \alpha \, (I_c)^{-ß} \quad \ldots 1$$

Where α (Alpha) and ß (Beta) are two constant for a particular liquid limit and their values are tabulated in Table-3 below:

Table-3: Values of α and ß for different values of liquid limit

SL No.	Liquid Limit(%)	α (Alpha)	ß (Beta)	Coefficient of Determination R^2
1	30	0.042	0.81	0.983
2	35	0.068	0.79	0.987
3	40	0.095	0.77	0.983
4	45	0.118	0.75	0.972
5	50	0.148	0.74	0.934
6	55	0.179	0.72	0.928
7	60	0.205	0.71	0.935
8	65	0.224	0.69	0.912
9	70	0.254	0.67	0.9
10	75	0.284	0.66	0.885

The value of α and ß from table-3 are plotted against liquid limit in fig-3 and fig-4 respectively

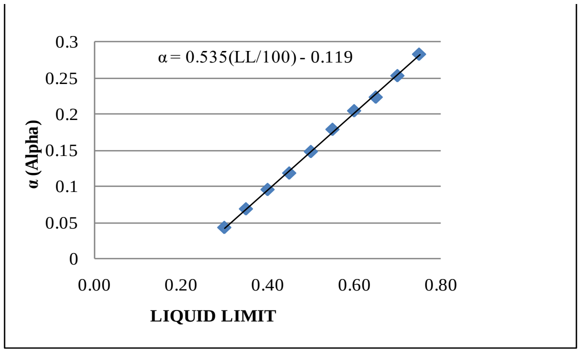

Fig-3: Variation of α (Alpha) values with Liquid Limit (LL).(R^2=0.998)

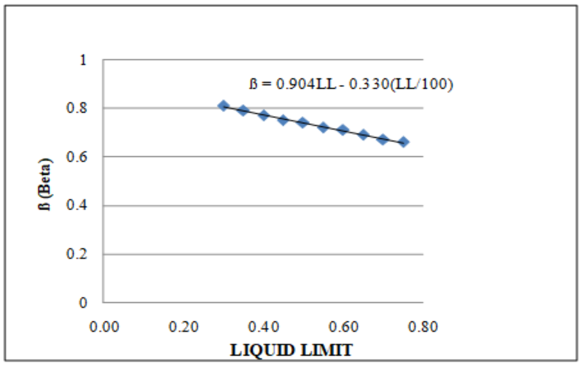

Fig-4: Variation of ß (Beta) values with Liquid Limit (LL). (R^2=0.995)

From these figures it is seen that relationship between α and liquid limit, and ß and liquid limit maybe expressed in linear form as

$\alpha = 0.535\,\frac{LL}{100} - 0.119$ …2

$ß = 0.904 - 0.330\,\frac{LL}{100}$ …3

Thus a general relationship between compression index (C_c) and consistency index (I_c) of a cohesive soil having liquid limit (LL), is

$C_c = \alpha\,(I_c)^{-ß}$

Where, $\alpha = 0.535\,\frac{LL}{100} - 0.119$

$ß = 0.904 - 0.330\,\frac{LL}{100}$

IV. VALIDATION OF THE PRESENT CORRELATION

For validation of the proposed correlation for compression index (Cc) with consistency index and liquid limit of soil, results of compression index, consistency index and liquid limit reported by different researchers in literature are utilized. The experimental results are shown in Table-4 below.

Table-4: Reported results of compression index of cohesive soils by different researchers.

SL No	REFERENCES	LL(%)	PL(%)	Wn(%)	Cc	SL No	REFERENCES	LL(%)	PL(%)	Wn(%)	Cc
1	Satyanarayana et al.(2009)	64	30	73.4	0.80	43	Jacob et al.(2016)	92	46	68	0.57
2		65	32	70	0.83	44		73	39	55	0.43
3		63	31	74.5	0.92	45		112	54	83	0.69
4		68	34	85.2	0.94	46		70	37	51	0.43
5		62	31	81.9	0.92	47		103	47	72	0.59
6		65	32	70	0.81	48		111	53	80	0.67
7		76	34	83.6	0.97	49		106	47	78	0.65
8		71	34	82.3	0.91	50		69	37	50	0.42
9		65	31	71.9	0.76	51		102	50	75	0.63
10		68	33	80.7	0.92	52		70	37	51	0.43
11		61	30	60.5	0.72	53		96	48	71	0.59
12	Satyanarayana et al.(2010)	86	35	90	0.99	54		80	43	60	0.53
13		75	34	85	0.99	55		78	41	57	0.48
14		88	35	77.6	0.96	56		75	39	56	0.43
15		76	34	81.1	0.93	57		77	41	50	0.45
16		68	31	75.9	0.91	58		112	54	83	0.69
17		95	34	80	0.88	59		109	53	81	0.67
18		91	32	77	0.84	60		75	39	55	0.46
19		100	34	75	0.83	61		71	41	62	0.48
20		71	31	76	0.80	62		72	42	50	0.48
21		63	30	75	0.76	63		72	38	54	0.42
22	Radhakrishnan and Suriyanarayanan (2010)	110	42.5	95	1.00	64		74	41	55	0.46
23	Jacob et al.(2016)	79	43	64	0.55	65		112	64	93	0.77
24		90	44	65	0.56	66		131	69	95	0.79
25		105	54	75	0.63	67		69	42	62	0.49
26		86	44	63	0.53	68		73	43	60	0.52
27		99	49	73	0.61	69		89	44	67	0.57
28		115	56	80	0.67	70		78	41	57	0.48
29		119	57	90	0.75	71		115	59	82	0.68
30		96	46	68	0.57	72		119	59	85	0.71
31		110	54	84	0.70	73		107	52	79	0.66
32		70	29	51	0.38	74		79	41	58	0.49
33		68	33	52	0.41	75		88	45	65	0.54
34		83	43	61	0.51	76		92	44	60	0.56
35		94	47	69	0.58	77		95	46	60	0.58
36		81	43	63	0.55	78		115	54	87	0.72
37		105	47	74	0.60	79		75	39	55	0.46
38		109	47	73	0.61	80		100	47	71	0.59
39		110	50	81	0.67	81		82	43	63	0.52
40		106	52	78	0.65	82		79	41	55	0.46
41		73	39	53	0.45	83	Bindu et al.(2017)	126	42.4	73.5	0.80
42		107	52	82	0.68	84		118.8	39.4	75	0.76

From the above table it is observed values of LL PL and w_n of cohesive soil tested for consolidation are given along with the experimental values of compression index. From the given values the consistency index of the soil was found. For the reported liquid limit values of alpha and beta factors were found from equation 2 and 3 from the proposed correlation model. From equation 1 substituting value of alpha beta and consistency index (I_c) of the soil predicted value of C_c was calculated. However it is to be observed from the table-4 that w_n of the soil for which experimental value of C_c are given, are having natural moisture content much above the value of liquid limit that is I_c is lesser than 0. However in such cases its seems impossible to run physically without disturbing the soil itself during collection at the site, transportation of the field and preparation of the sample at the laboratory. However example of such cases are many and in such cases consistency index of such samples are taken as a small value of 0.15 and compression index of such soils are predicted with I_c=0.15.

These predicted values of compression index from present analysis are then compared with experimental values of compression index. For the visual compression between predicted and experimental values of compression index both the values are plotted against each other in Fig- 5.

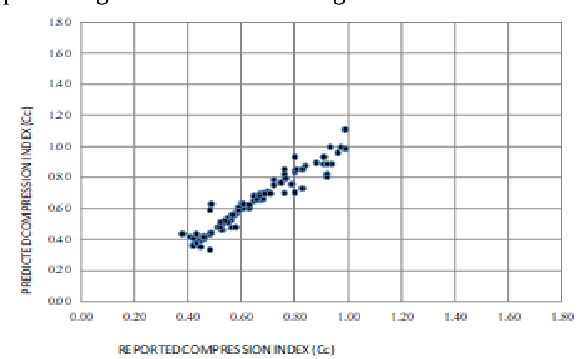

Fig:-5 Comparison of Predicted Compression index (C_c) values with Reported Compression index (C_c) values.

In fig-5 three lines passing through origin having slope $\frac{Cc\ predicted}{Cc\ experimental}$ = 0.9, 1.0 and 1.1 are drawn respectively. Most of the plotted points lie within the zone bounded by $\frac{Cc\ predicted}{Cc\ experimental}$ =0.9 and 1.1 respectively, indicating percentage error in prediction lying between below ±10% of experimental value, indicating quits satisfactory and acceptable correlations.

V. SUMMARY AND CONCLUSION

On the basis of presentation following conclusions are drawn

1. An unique relationship between compression index (C_c) of cohesive soils with consistency index (I_c) and liquid limit (LL) of the soil has been set up, in the form of
   $C_c = \alpha\ (I_c)^{-ß}$
   Where, α and ß depend on the value of liquid limit of the soil in the form
   $\alpha = 0.535\,\frac{LL}{100} - 0.119$
   $ß = 0.904 - 0.330\,\frac{LL}{100}$
2. The presented correlation successfully explains the general behavior of cohesive soils of exhibiting greater compression index when natural water content approaches value of liquid limit and lesser compression index when nature water content approaches the value of plastic limit of this soil.
3. Further the present correlation predicts the normal behavior of cohesive soils, exhibiting greater compressibility at same value of consistency index for a soil having higher liquid limit than the other.
4. Validity of this presented correlation has been established on the basis of published results of compression index, liquid limit, plastic limit and natural water contents of cohesive soils, by different researchers in available literature. The prediction shows results lying within ±10% of experimental values of the compression index, reported for the soils.

REFERENCES

[1] A.W. Skempton, -Notes on the compressibility of clays,‖ Quarterly Journal of the Geological Society, vol. 100(14),pp.119–135,1944.

[2] A.S. Azzouz, R.J. Krizek, R.B. Corotis, -Regression analysis of soil compressibility,‖ Soils and Foundations, vol.16(2),pp.19–29,1976.

[3] A. Sridharan, H. Nagaraj, -Compressibility behaviour of remoulded, fine-grained soils and correlation with index properties,‖ Canadian Geotechnical Journal, vol. 37(3),pp.712–722,2000.

[4] A. Nath, S. Dedalal, -The role of plasticity index in predicting compression behaviour of clays,‖ Electronic Journal of Geotechnical Engineering, vol.9,pp.1–7,2004.

[5] B.K. Hough, -Basic Soils Engineering,‖ Ronald Press Conference, New York, pp.114–115,1957.

[6] B.C. Chattopadhyay, -Report on Soil Investigation for Proposed Housing Project,‖ Submitted to H.I.T. Bengal Engineering And Science University, Shibpur, 2007.

[7] B. Satyanarayana, C.N.V. Satyanarayana Reddy, -Empirical correlations of compressibility of marine clays—a review,‖ Indian Geotechnical Conference, Guntur, India, 2009.

[8] B. Satyanarayana, C.S. Reddy, -Development of empirical Equation for compressibility of marine clays,‖ In Proc. Of Indian Geotechnical Conference, December, pp. 16-18, 2010.

[9] C.P. Worth, D.M. Wood, -The Correlation of Index Equation with Some Basic Engineering Properties of Soils,‖ Canadian Geotechnical Journal, vol.15,pp.137–145,1978.

[10] D.P. Sengupta, -Fore Casting of Compression Index,‖ India Geotechnical Journal, vol.3, pp.256–263,1974.

[11] D. Roy Chowdhury, -Microzonation of Newtown, Proposed Metro Project, Kolkata for Liquefaction Potential,‖ A Thesis submitted in partial fulfillment of the requirement for the degree of Master of Technology, Maulana Abul Kalam Azad University of Technology, Kolkata, India, 2016.

[12] D.G. de Oliveira, M. Thewes, M.S. Diederichs, L. Langmaack, -Consistency index and its correlation with EPB excavation of mixed clay–sand soils,‖ Geotechnical and Geological Engineering, vol.37(1), pp.327-345,2019.

[13] F. Ogawa, -Correlation of the mechanical and index properties of soils in harbour districts,‖ Report of the Port and Harbour Research Institute, Harbour, vol.17(3),pp.3–89,1978.

[14] F.M. Abdrabbo, M.A. Mahmoud, -Correlations between index tests and compressibility of Egyptian clays,‖ Soils and Foundations, vol.30(2),pp.128–32,1990.

[15] G.B. Sowers, -Introductory Soil Mechanics and Foundations,|| 3rd edn. Macmillan, London, UK (1970).
[16] H.T.R. Yamagutshi, -Characteristics of alluvial clay,|| Report of Kyushyu Agriculture Investigation Centre of Japan, Japan, vol. 5(4),pp.349–358,1959.
[17] H. Taniguchi, T. Abe, M. Goto, -Engineering properties of basement clay in Ishikari peat layer,|| in: Proc. 5th Engineering Symposium of Hokkaido Development Bureau, 1960.
[18] H. Taniguchi, -Engineering properties of basement clay in rumoi harbor,|| Tsuch-to-Kisso, JSSMFE, vol.49,pp.19–27,1962.
[19] H. Shouka, -Relationship of compression index and liquid limit of alluvial clay,|| in: Proc. 19th Japan Civil Engineering Conference, Tohoku, pp. 30–31,1964.
[20] J.E. Bowels, -Foundation Analysis Design,|| McGraw-Hill lnt. Book Company, Auckland, pp. 49, 1982.
[21] J. E. Bowles, -Physical and geotechnical properties of soils,|| McGraw-Hill lnt. Book Company, New York, 1989.
[22] J. Park, T. Koumoto, -New compression index equation,|| Journal of Geotechnical and Geo-environmental Engineering, vol.130(2),pp.223–6,2004.
[23] J. Bindu, K. Kannan, S. Sajna, - Biocementation in Marine Clays: Effect on Grain Size Distribution,|| Indian Geotechnical Conference 2017, IIT Guwahati, India, December,2017.
[24] K. Terzaghi, -Determenation of the consistency of soils by means of penetration tests,|| Public Roads, vol7, pp.–230-247,1926.
[25] Kyushu branch of JSSMFE, -The ground around the Ariake sea,|| JSSMFE, vol. 7(4),pp.31–36,1959.
[26] K. Terzaghi, R.B. Peck, -Soil mechanics in engineering practice,|| 2nd edn. John Wiley & Sons, New York, 1967.
[27] K. Jacob, G. Hari, -Study on the relationship of shear strength from water content, Atterberg limits and field density for Kuttanad clay,|| International journal of innovative research in technology, vol.3(4),pp. 9-16,2016.
[28] K. Chatterjee, -Soil Mapping in Newtown Area in Kolkata,|| A Thesis submitted in partial fulfillment of the requirement for the degree of Master of Technology, Maulana Abul Kalam Azad University of Technology, Kolkata, India, 2016.
[29] M. Serajuddin, -A Study of the Engineering Aspects,|| Journal of the Institution of Engineers Pakistan, vol.9(1),pp.610,1969.
[30] M.N. Amin, G.P. Shah, M.H. Kabir, M. Ahmed, -Geotechnical Behavior of Soils from Coastal Region of Bangladesh,|| in: Proc. 9th Southeast Asian Geotechnical Conference, Bangkok, Thailand, 1987,pp. 5–12.
[31] M. Serajuddin, -Universal compression index equation and Bangladesh soils,|| In: Proc. 9th Southeast Asian Geotechnical Conference, Bangkok, Thailand, pp. 61–72,1987.
[32] O. Rendon-Herrero, -Universal Compression Index Equation,|| Journal of Geotechnical Engineering, vol.109(5),pp.755–761,1980.
[33] O. Herrero, -Universal compression index equation,|| Journal of Geotechnical Engineering, ASCE, vol.109(5),pp.755–761,1983.
[34] P.W. Mayne, -Cam-clay predictions of undrained strength,|| Journal of the Geotechnical Engineering Division, ASCE, vol.106(11),pp.1219–1242,1980.
[35] R. Radhakrishnan, N.S. Suriyanarayanan, -Embankment construction over reclaimed land using pre-fabricated vertical drains,|| In Proceedings of IGC, India, Decemer,2010.
[36] S. Murayama, K. Akai, K. Ueshita, -Engineering properties of alluvial clays in Osaka,|| Soils and Foundations, vol. 6(4),pp.39–47,1958.
[37] S.D. Koppula, -Statistical Estimation of Compression Index,|| Geotechnical Testing Journal, vol.4(2),pp.68–73,1981.
[38] S. Hirata, S. Yao, K. Nishida, -Multiple regression analysis between the mechanical and physical properties of cohesive soils,|| Soils and Foundations, vol.30(3),pp.91–108,1990.
[39] S. Dey, B.C. Chattopadhyay, - Compression Index of Cohesive Soils and Its Prediction,|| International journal of innovative research in technology, vol.7(9),pp. 273-280,2021.
[40] T.W. Lambe, R. V. Whitman, -Soil mechanics. John Willey & Sons,|| Inc., New York 553 ,1969.
[41] T. Nagaraj, S. Murthy, -Rationalization of Skempton's compressibility equation,|| Geotechnique, vol.33(4),pp.433–443,1983.

[42] T.S. Nagaraj, R. Basavapatna, S. Murthy, -Prediction of the pre-consolidation pressure and recompression index of soils,|| Geotechnical Testing Journal, vol.8(4),pp.199–202,1985.
[43] T.S. Nagaraj, et.al., -Stress-state-time-permeability relationships for saturated soils,|| In: Proc. International Symposium on Compression and Consolidation of Clayey Soils, Hiroshima, pp. 537–542,1995.
[44] T. Nagaraj, N. Miura, -Soft clay behaviour analysis and assessment,|| 1st edn. CRC Press, London, 2001.
[45] V. Cozzolino, -Statistical forecasting of compression index,|| In: Proc. 5th Int. Conf. Of SMFE, Paris, pp. 51–53, 1961.
[46] V.A. Nacci, M.C. Wang, K.R. Demars, -Engineering behavior of calcareous soils,|| American Society of Civil Engineers, vol.1,pp.380–400,1975.
[47] V.K. Jain, M. Dixit, R. Chitra, -Correlation of Plasticity index and Compression index of Soil,|| International Journal of Innovations in Engineering and Technology (IJIET), vol.5(3),pp.263–270, 2015.
[48] Y. Nishida, -A brief note on compression index of soil,|| Journal of the Soil Mechanics and Foundations Division, vol.82(3),pp.1–14, 1956.