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Assessment of Sedimentary Basin effect on Soil Structure in Kerman City Deposits Using Destructuring Coefficient Criterion

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Abstract: Destructuring coefficient is an index that shows effect of geological history and sedimentary processes on formation of fabric and structure in fine soils. In this research, the necessary studies for determining destructuring coefficient in Kerman city deposits were done by the behavior of natural and reconstituted soils. Thus, at first, reconstituted consolidation curves for the deposits called intrinsic compression curve was extracted. For evaluating soil destructuring coefficient, three different methods which are applicable in evaluating soil destructuring coefficient were applied. Thus, the required parameters of any model were extracted and natural compression curves were compared with intrinsic compression line or curves; then soil destructuring coefficient was calculated using theoretical model. The results showed that range of destructuring coefficient was less than unit and structure and fabric of soils were not developed. Also, formation of cement between the grains was not complete.

Keywords: Sedimentary model, natural sedimentation compression curve, intrinsic compression line, fabric, Kerman city, destructuring coefficient, Iran.

INTRODUCTION

Kerman city has widespread fine grained deposits that are formed in a special sedimentary basin that influence geotechnical parameter of soils. It is very important to consider effect of historical factors and depositional environment on geological and geotechnical characteristics of soil. Engineering characteristics of fine grained soils are different in Kerman plain, the reason for which is the influence of geological properties, like bed rock, mineralogy, sediment transport (wind, water and glaciers), transportation distance, sediments age, posturing of grains, weathering and faulting. Hence, these factors have an important influence on engineering parameter of fine grained soils. Formation and development of soil structure often produce anisotropy in the mechanical properties of soil (Liu and Carter, 2003). Compression behavior of geomaterials has always been a topic of investigation in geotechnical engineering (Pestana and Whittle, 1995). Many studies have been made to assess in-situ mechanical behavior of natural sedimentary soils (Burland, 1990; Leroueil and Vaughan, 1990; Hong and Tsuchida, 1999; Cotecchia and Chandler, 2000). It has been widely recognized that soils generally behave differently from reconstituted soils due to the effect of soil structure (Locat and Lefebvre, 1986; Schmertmann, 1991). In this research, the relationship between sedimentary basin model and geological history and engineering properties of Kerman city deposits was considered using destructuring coefficient.

SEDIMENTARY BASIN MODEL

Physiographic shape of Kerman sedimentary basin was due to tectonic movements of Quaternary period. Kerman plain is located in a depression between Kuhbanan-Mahan mountain ranges in the east and Badamo-Davaran in the west and has a graben structure formed by circumferential reverse faults (Fig.1). Kerman city is a part of Kerman plain and, in the present study, all assessment and analysis were done on Kerman city soils. Kerman deposits are fine grained alluvial materials mainly composed of silt and clay (CL-ML). Kerman plain, a closed basin, received all the flood sediments from high areas during Pleistocene and four major glacial periods. Sedimentation rate are controlled by many known factors such as watershed basin physiography, sediment supply and sediment texture (Amini, et.al). Transportation and deposition of flood materials was done proportional to flood energy in depression and low land areas and has formed Kerman plain. In upper Pleistocene, due to

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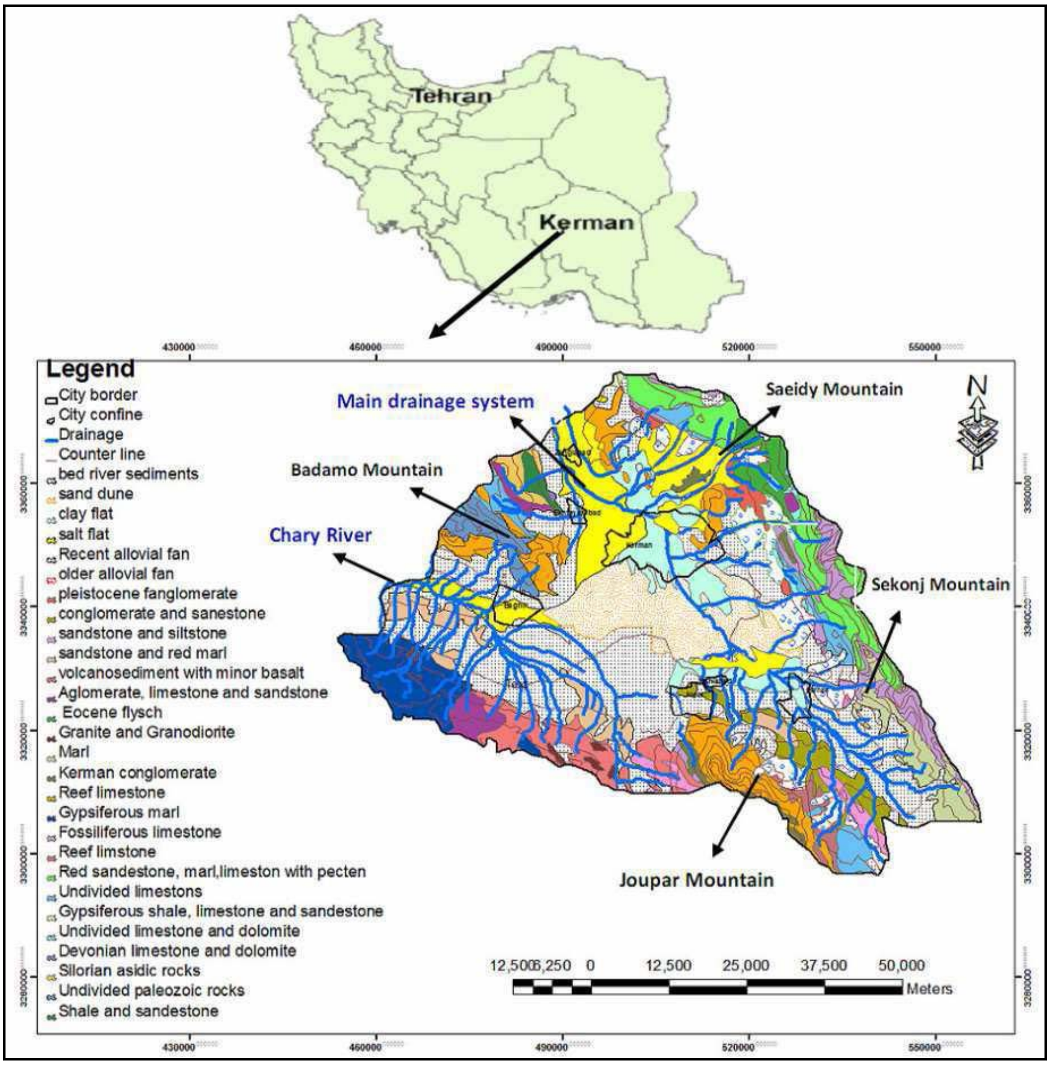

Fig.1. Kerman sedimentary basin reproduced from 1:500000 geological maps.

tectonic movements, condition of closed basin has been varied and Kerman sedimentary basin gently sloped to the north and northwest direction (Kadijar et al. 1996).

MATERIALS AND METHODS

Destructuring coefficient is an indicator of levels of fabric development, structure and cementation in fine soils. In this study, for evaluating soil destructuring coefficient, three different methods that were more applicable in evaluating destructuring coefficient of fine soils were used. Recently, in formulating constitutive models, influence of soil structure is incorporated (Gens and Nova, 1993; Whittle, 1993; Wheeler, 1997; Rouainia and Muir Wood, 2000; Kavvadas and Morosi, 2000).

In models presented by Liu and Carter (1999, 2000), natural and reconstituted consolidation curves were compared with each other. But, in the method proposed by Haydari (2001), natural compression curves were compared with intrinsic compression line (ICL). Therefore, at first, all the reconstituted consolidation curves were normalized by void index parameter (Iv) that was proposed by Burland (1990) and intrinsic compression line (ICL) of Kerman city sediments were extracted. Finally, the parameter belonging to each method was extracted and destructuring coefficient was calculated for every soil sample. Consolidation tests of soils were performed in soil mechanics and technical laboratory of Kerman province. In the models proposed by Liu and Carter (1999 and 2000), intrinsic and natural compression curves were compared in e-logσ'v space; but, in Haydari's (2001) method, the comparison of natural compression curves and intrinsic compression line (ICL) was performed in Iv-Log (σ'v) space. Based on the distance between sedimentation compression curves (SCCs) and intrinsic compression line (ICL), destructuring coefficient of soils and cementation phenomena could be realized. If cementation process occurred in the initial stage of sedimentation and continued an upper surcharge was added to the upper soil, than the distance between sedimentation compression curves and intrinsic compression line would be added. However, if the bonds between the particles were formed after primary sedimentation process without using the upper surcharge, the distance between SCCs and ICL would be negligible and might even intersect each other.

MODELS OF SOIL DESTRUCTURING COEFFICIENT

Model 1 (Heydari, 2001)

To determine destructuring coefficient, behavioral compressibility of natural and reconstituted soils are compared with each other. Figure 2 introduces the parameters and their manner of measurement which is used in model 1. Soil behavior after the yield point can be expressed by equation (1):

$$Iv_N = Iv_R + \Delta I_V \quad (1)$$

where Iv_N is void index of soil in natural state for virgin compression curve and Iv_R is void index of reconstituted soil in the same stress state.

To provide a theoretical model for rapid degradation of soil structure during virgin consolidation, equation (2) is recommended:

$$\left(\frac{\Delta Iv}{\Delta Iv_i}\right) = \left(\frac{\sigma' vy}{\Delta Iv_i}\right) A \quad (2)$$

In this model, it is assumed that $\sigma' v_i$ is always greater than or equal to $\sigma' vy$. Namely, the model is developed for a range in which soil structure is destroyed. ΔIv_i is difference of void index of soil in natural and reconstituted states in the yield point. ΔIv is difference of void index of soil in natural and reconstituted states in any stress larger than yield point. Destructuring coefficient value (A) could theoretically vary between zero and infinity:

$$0 \leq A \leq \infty$$

Practical variation range of destructuring coefficient (A) for soils is between 0 and 30. For stiff soils, value of this coefficient is less than unit.

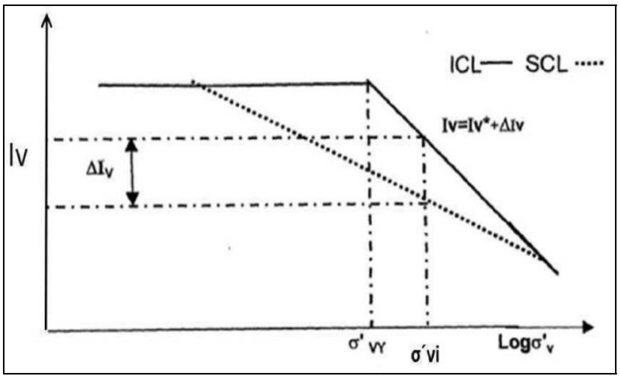

Fig.2. Idealization behavior of reconstituted and structured soils Model 1 (Heydari, 2001).

Model 2 Liu and Carter (1999)

In this model the compression behavior of reconstituted and structured soils is shown (Fig.3).

To determine the structure index of soils, following relationships has been proposed by Liu and Carter (1999).

$$S = \Delta e / \{(P'yi/P')*Ln(P'yi)\} \quad (3)$$

where S is a soil parameter, described as the 'structure index'.

A is not a soil structure parameter, and its value is dependent on the initial virgin yield stress as well as the deformation constraints imposed during the compression. The currently available test data do not enable the derivation of an explicit and definitive expression for A. A simple equation for A is suggested (4).

$$A = Sp'y,i*Lnp'y,i \quad \text{for } p' > p'y,i \quad (4)$$

p'y, i represents the yield stress and p' (current mean effective stress) is the desired stress that is higher than the yield stress.

Model 3: Liu and Carter (2000)

Compression behavior of reconstituted and structured soils (Liu and Carter, 2000) is shown in Fig. 4.

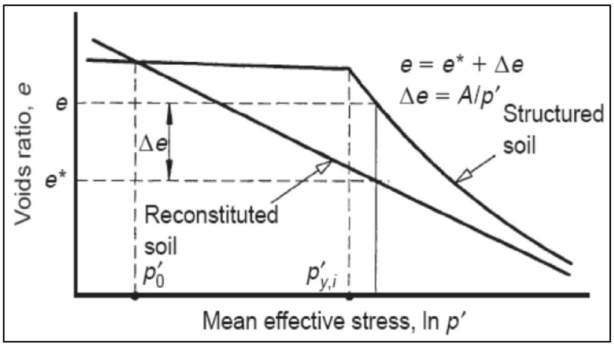

Fig.3. Idealization of behavior of reconstituted and structured soils based on Model 2 (Liu and Carter, 1999).

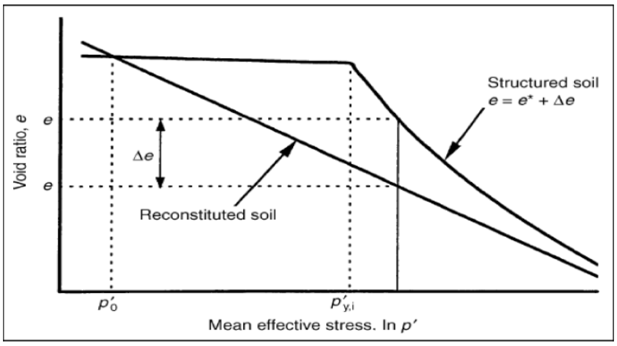

Fig.4. Behavior of reconstituted and structured soils Model 3 (Liu and Carter, 2000).

where p' is the mean effective stress, e represents the voids ratio for a structured soil, e* is the voids ratio for the corresponding reconstituted soil at the same stress state during virgin yielding, p'y,i is the mean effective stress at which virgin yielding of the structured soil begins, and Δe, the additional voids ratio, which is the difference in voids ratio between a structured soil and its corresponding reconstituted soil. Hence, the virgin compression behavior of a structured soil can be expressed by equation (5).

$$e = e^* + \Delta e \quad (5)$$

For determining the destructuring rate of structured soils during virgin compression, a new equation is proposed as (6) and (7) relationships:

$$\Delta e = \Delta ei(p'yi/p')^b \quad \text{for} \quad p' > p'y,I \quad (6)$$

$$b = \{Log(\Delta e/\Delta ei)\}/\{Log(p'yi/p')\} \quad (7)$$

Δei, is the additional voids ratio at p' = p'y,i, where virgin yielding begins. Δe , difference of void ratio for structured soil with the reconstituted soil in stresses without yield stress. b =The compression destructuring index that is a new parameter to quantifying the rate of destructuring.

INTRINSIC COMPRESSION LINE OF KERMAN SEDIMENTS

To plot intrinsic compression line for Kerman city's fine grained soils (Kerman city's soils-ICL), 25 disturbed samples (Table 1) were prepared from 11 proper sites in Kerman city (Fig.2). Then, the samples were mixed with high amounts of water content, usually between 1.0 and 1.5 times of liquid limit of the material (preferably 1.25 times), without air or oven drying prior to the reconstitution.

The prepared slurry was poured in a one-dimensional consolidation tube and was consolidated by vertical static loads applied to the samples. Values of void ratios were calculated for different levels of stress and consolidation

Table 1. Location of sites that soil samples are obtained and reconstituted in Kerman city arena

Site Location	Depth (m)	Long.	Latitude	Abbre-viation Code
Kerman potk company	8	502715	3350784	Ke-1
Kerman potk company	18	502715	3350784	Ke-2
Aspect and sound organization	4	508517	3347346	Ad-1
Aspect and sound organization	10	508517	3347346	Ad-2
Aspect and sound organization	14	508517	3347346	Ad-3
Aspect and sound organization	16	508517	3347346	Ad-4
Aspect and sound organization	20	508517	3347346	Ad-5
Forensic medicine	12	502330	3352324	Fo-1
Forensic medicine	18	502330	3352324	Fo-2
Forensic medicine	20	502330	3352324	Fo-3
Forensic medicine	26	502330	3352324	Fo-4
Abozar bridge	5	505595	3347973	Abo-1
Abozar bridge	10	505595	3347973	Abo-2
Kohpayeh four way	13	508179	3353925	Ko
Baghodrat four way	18	507789	3346876	Ba
Abas sabahy avenue	7	506818	3351388	Aba-1
Abas sabahy avenue	14	506818	3351388	Aba-2
Kusar four way	8	501962	3351323	Ku-1
Kusar four way	24	501962	3351323	Ku-2
Kusar four way	30	501962	3351323	Ku-3
Council park	10	507183	3351530	Co-1
Council park	30	507183	3351530	Co-2
Council park	40	507183	3351530	Co-3
Firozeh avenue	5	504601	3350111	Fi
Jahad avenue	15	505007	3352222	

curves of all the samples were drawn together in a void ratio – vertical stress space or e-log (σ'ν) space. Then, two important quantities were obtained and used when dealing with intrinsic compression curve. They were e*100 and e*1000, in which mean intrinsic void ratios corresponded to values of effective stress σ'ν = 100 kPa and σ'ν = 1,000 kPa, respectively. Intrinsic compression index Cc* was defined as e*100 - e*1000.

Due to differences of void ratio, liquid limit and mineralogy of sediments at various depths, intrinsic compression curves for reconstituted clay soils plotted in e-logσ'ν space were different from each other and covered a wide range (Fig.3).

Therefore, in order to achieve a single intrinsic consolidation line as basis for comparing natural and reconstituted soils, the proposed normalizing parameter called void index (Iv) was used (Burland, 1990) which is defined as equation (8).

$$I_V = (e - e^*100) / (e^*100 - e^*1000) \quad (8)$$

The normalized results were plotted in the Iv-Log (σ'í) space and the best fitted line called intrinsic compression line (ICL) was obtained for fine grained sediments (Fig.4) by the equation (9).

$$Iv = 1.998\text{-}0.43Ln(\sigma'\nu) \quad (9)$$

Equation of intrinsic compression line of Kerman deposits has suitable overlap with ICL (Burland, 1990) and

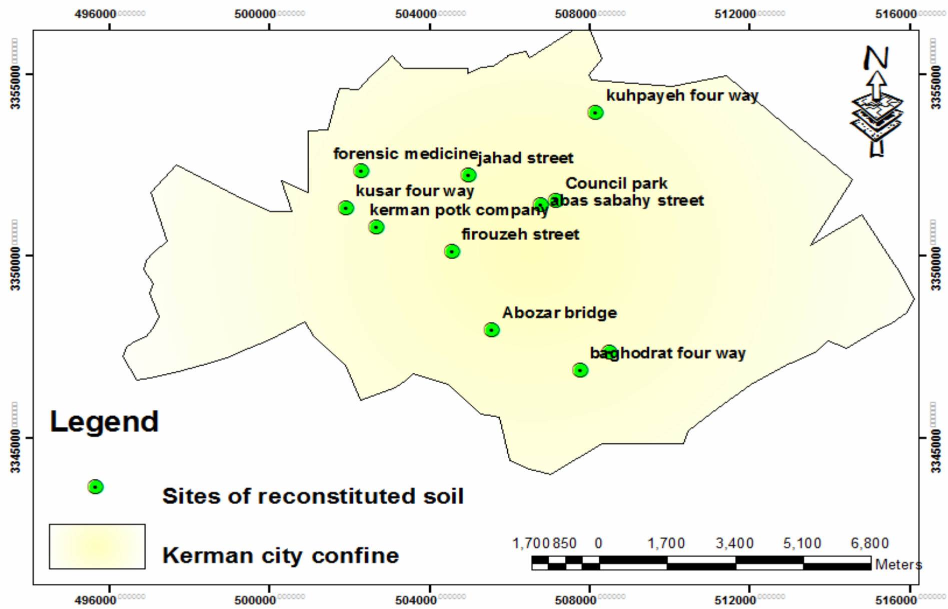

Fig.5. characteristic of sites that soil samples are obtained

they had slight difference in the range of low stresses (Fig.5).

Evaluating Destructuring Coefficient in Kerman City Deposits by Model 1

For evaluating destructuring coefficient by model 1, natural sedimentation compression curves were normalized by the void index as suggested by Burland (1990) and plotted on Iv-Log (σ'v) space. Then, sedimentation compression curves for each soil sample were compared with the intrinsic compression line of Kerman city sediments. The required parameters ΔIvi (differences of void index of natural and reconstituted consolidation curves in yield stress), ΔIv (differences of void index of natural and reconstituted curves in higher than yield stress), σ' vy (yield stress) and ó’vi (stress level, except yield stress) for each soil sample were obtained and finally the destructuring coefficient was calculated based on model 1. An example is shown in Fig.9 and other results are given in Table 2. The natural sedimentation compression curves that are used in calculating destructuring coefficient based on model 1 for another sample are presented in Fig.10. In this method, position and distance of sediment consolidation curves to intrinsic compression line is important. The samples located on the left of ICL were more compact and had less structural development. Considering Fig.10, it can be seen that location of natural sedimentation compression curves were on the left of ICL and showed that destructuring coefficient in sediments was generally less than unit and soil structure was not developed.

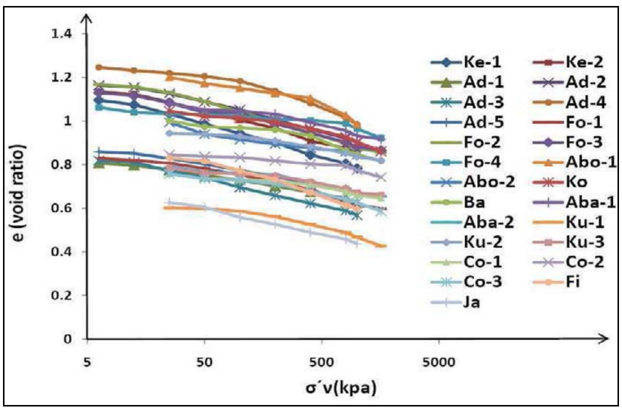

Fig.6. Intrinsic compression curves of Kerman sediments in e-Log(σ'v) space.

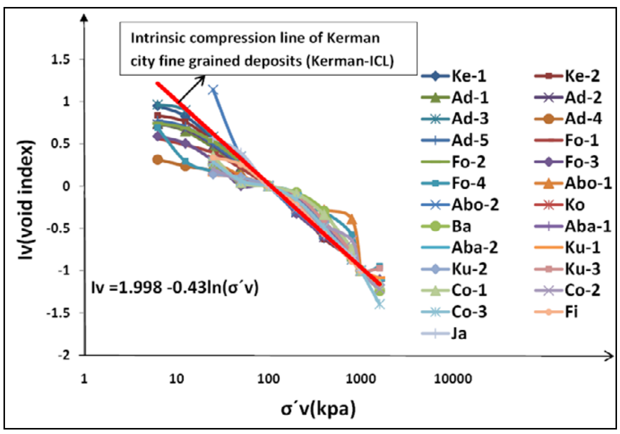

Fig.7. Best fitted line to normalized intrinsic curves of Kerman city sediments

Table 2. Destructuring coefficient for Kerman city sediments based on model 1

Borehole location	depth	σ'vy	σ'vi	ΔIv_i	ΔI_v	Destruturing coefficient, Model 1
Kerman potk company	8	25	400	- 0.865	-0.2936	0.4692
Kerman potk company	18	25	100	-0.624	-0.325	0.576
Aspect and sound organization	4	50	200	- 0.479	-0.321	0.434
Aspect and sound organization	10	100	800	- 1.804	-1.688	0.045
Aspect and sound organization	14	50	1000	-1.491	-1.020	0.171
Aspect and sound organization	16	50	200	- 0.533	-0.285	0.517
Aspect and sound organization	20	50	400	-1.384	-1.102	0.151
Forensic medicine	12	50	800	-1.612	-1.345	0.100
Forensic medicine	18	50	100	-0.44	-0.233	0.419
Forensic medicine	20	100	800	-3.092	-2.726	0.068
Forensic medicine	26	100	1000	-1.655	-1.248	0.161
Abozar bridge	6	50	200	-2.256	-2.067	0.085
Abozar bridge	10	50	200	-2.675	-2.571	0.048
Kuhpayeh four way	13	100	1000	-2.412	-2.044	0.085
Council park	10	100	800	-2.190	-2.073	0.105
Council park	40	50	1000	-1.140	-1.099	0.165
Kusar four way	8	50	800	-1.19	-0.818	0.192
Kusar four way	24	200	400	-2.130	-1.94	0.456
Kusar four way	30	200	800	-2.180	-1.547	0.302
Baghodrat four way	18	50	1000	-1.113	-0.471	0.287

Table 3. Destructuring coefficient result based on model 2

Borehole location	Latitude	Longitude	Depth	P'yi	P'	Δe	Δei	b
Kerman potk company	502715	3350784	8	25	800	-0.079	-0.223	0.2994
Kerman potk company	502715	3350784	18	25	800	-0.134	-0.248	0.1774
Aspect and sound organization	508517	3347346	4	25	800	-0.102	-0.07	0.146
Aspect and sound organization	508517	3347346	10	50	400	-0.102	-0.458	0.722
Aspect and sound organization	508517	3347346	14	200	1000	0.0148	0.0232	0.276
Aspect and sound organization	508517	3347346	16	50	400	-0.323	-0.387	0.0869
Aspect and sound organization	508517	3347346	20	50	400	-0.056	-0.084	0.1949
Forensic medicine	502330	3352324	12	50	400	-0.054	-0.09	0.2456
Forensic medicine	502330	3352324	18	50	800	-0.156	-0.247	0.1657
Forensic medicine	502330	3352324	20	100	400	-0.488	-0.534	0.0649
Forensic medicine	502330	3352324	26	50	1000	-0.275	-0.294	0.0223
Abozar bridge	505595	3347973	6	25	50	-0.555	-0.576	0.046
Abozar bridge	505595	3347973	10	25	100	-0.367	-0.41	0.079
Kuhpayeh four way	508179	3353925	13	50	800	-0.452	-0.482	0.0231
Council park	507183	3351530	10	50	800	-0.154	-0.163	0.0204
Council park	507183	3351530	30	100	800	-0.067	-0.106	0.2206
Council park	501962	3351323	40	50	400	-0.025	-0.42	0.2494
Kusar four way	501962	3351323	8	50	800	-0.192	-0.154	0.0138
Kusar four way	501962	3351323	24	50	1000	-0.33	-0.339	0.0089
Kusar four way	507789	3346876	30	50	800	-0.115	-0.121	0.0183
Baghodrat four way	502715	3350784	18	25	200	-0.013	-0.036	0.0876

Table 4. Destructuring coefficient result based on model 3 (Liu and Carter, 2000)

Borehole location	depth	p'y,i	p'	Δe	S=Δe/{(P'y,i/P')*Ln(P'y,i)}	A=S*p'y,i*Lnp'y,i
Kerman potk company	8	25	800	0.079	0.785	63.17
Kerman potk company	18	25	800	0.134	1.332	107.18
Aspect and sound organization	4	25	800	0.102	1.014	81.59
Aspect and sound organization	10	50	400	0.102	0.2085	40.78
Aspect and sound organization	14	50	400	0.045	0.092	17.99
Aspect and sound organization	16	50	400	0.323	0.6605	129.19
Aspect and sound organization	20	50	400	0.056	0.1145	22.39
Forensic medicine	12	50	400	0.054	0.1104	21.59
Forensic medicine	18	50	800	0.156	0.638	124.79
Forensic medicine	20	100	400	0.488	0.4238	195.16
Forensic medicine	26	50	1000	0.275	1.421	277.94
Abozar bridge	6	25	50	0.555	0.3448	27.74
Abozar bridge	10	25	100	0.367	0.456	36.69
Kuhpayeh four way	13	50	800	0.452	1.848	361.47
Council park	10	50	800	0.154	0.6298	123.18
Council park	30	100	800	0.067	0.1164	53.60
Council park	40	50	400	0.025	0.0511	9.99
Kusar four way	8	50	800	0.192	0.7852	153.58
Kusar four way	24	50	1000	0.33	1.687	329.97
Kusar four way	30	50	800	0.115	0.4703	91.99
Baghodrat four way	18	25	200	0.013	0.0323	2.599

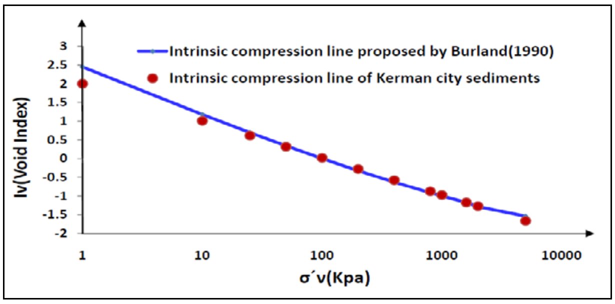

Fig.8. Comparison of Burland (1990) –ICL with Kerman city deposits – ICL

Evaluating Destructuring Coefficient of Kerman City Deposits by Model 2

To evaluate destructuring coefficient (S) for Kerman city soils by model 2 (Liu and Carter, 1999), natural and intrinsic compression curves were drawn in e-Log(σ'v) space and compared with each other for each sample. The model parameters such as Δei, P'yi and P' for each soil sample was obtained and destructuring coefficient was calculated. The results shown in Table 3 and the data indicate that destructuring coefficient (S) of Kerman soils was generally less than 1 and soil structure was not developed properly. An example is shown in Fig.11.

Evaluating Destructuring Coefficient of Kerman City Deposits by Model 3

To determine destructuring index of soils of the area by model 3 (Liu and Carter, 2000), natural and intrinsic compression curves were drawn in e-Log(σ'v) space and compared with each other for each soil sample.

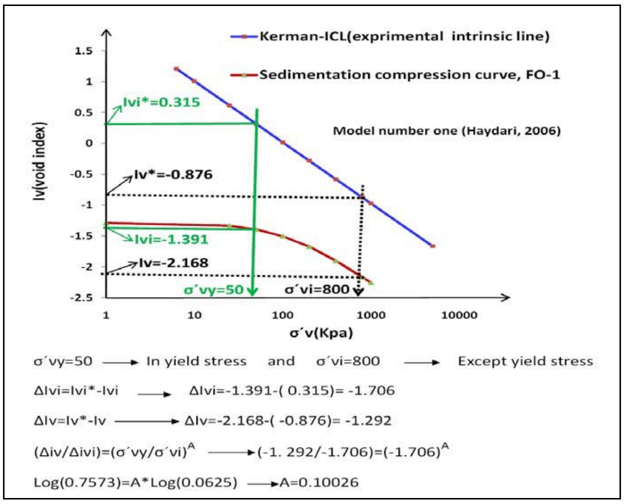

Fig.9. Calculation of destructuring coefficient based on model 1

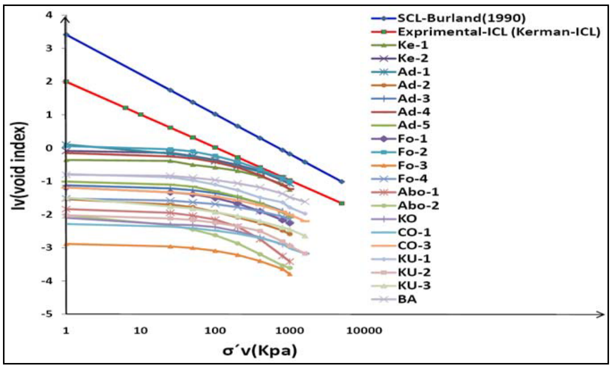

Fig.10. Sedimentation compression curves related to Kerman city deposits – ICL

The model parameters such as Δei (difference of void ratio in undisturbed and reconstituted soils in yield stress state), Δe (difference of void ratio in undisturbed and reconstituted soils at a stress level, except yield stress), P'yi (mean effective stress at yield stress) and P' (mean effective stress, except yield stress) were obtained for each soil sample and destructuring coefficient (b) was calculated 3. This is depicted in Fig.12 and other results are given in Table 4

CONCLUSIONS

Results of destructuring coefficient analysis showed that soil of Kerman city, was compressed and over consolidated and the structure was not highly developed. The reason could be that Kerman city is located on an extend flood plain and near the drainage system that was continuously exposed to erosion and sedimentation processes in the past. Therefore, deposited soils did not have enough time for cementation and formation of structure; but the weight of large amounts of upper layers that were deposited during long periods of sedimentation caused consolidation and compression of sub- layers. Therefore, results of destructuring coefficient

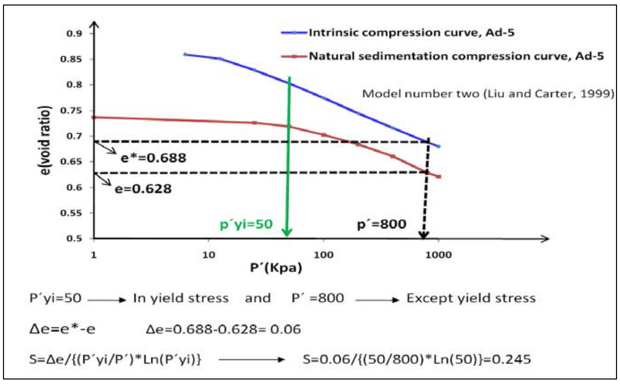

Fig.11. Calculation method of the destrucuring coefficient based on model 2.

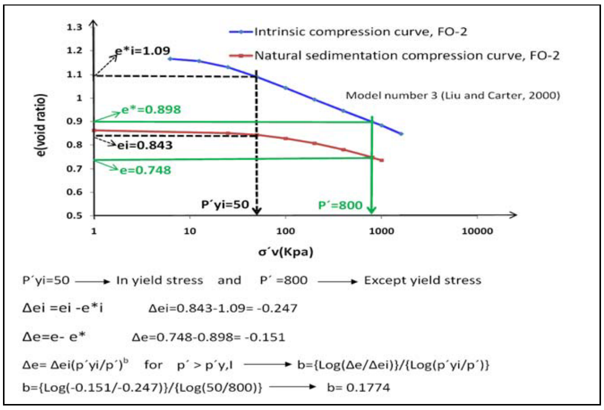

Fig.12. calculation method of the destrucuring coefficient based on model 3

analysis confirmed important role of depositional environment on engineering properties of soil of Kerman city area.

Further the overall results obtained from different methods were close and destructuring coefficient of soils was less than unit (Table 5).

Table 5. Result of destructuring coefficient calculation based on different model.

Borehole location	depth	model 1 with Kerman city-ICL (Haydari, 2006)	model 2 (Liu and Carter, 1999)	model 3 (Liu and Carter, 2000)
Kerman potk company	8	0.4692	0.785	0.2994
Kerman potk company	18	0.5766	1.332	0.1774
Aspect and sound organization	4	0.4339	1.014	0.146
Aspect and sound organization	10	0.0456	0.2085	0.722
Aspect and sound organization	14	0.1716	0.092	0.276
Aspect and sound organization	16	0.5179	0.6605	0.0869
Aspect and sound organization	20	0.1513	0.1145	0.1949
Forensic medicine	12	0.1002	0.1104	0.2456
Forensic medicine	18	0.914	0.638	0.1657
Forensic medicine	20	0.0686	0.4238	0.0649
Forensic medicine	26	0.1618	1.421	0.0223
Abozar bridge	6	0.0856	0.3448	0.046
Abozar bridge	10	0.0479	0.456	0.079
Kuhpayeh four way	13	0.0847	1.848	0.0231
Council park	10	0.1054	0.6298	0.0204
Council park	30	0.1648	0.1164	0.2206
Council park	40	0.1921	0.0511	0.2494
Kusar four way	8	0.4566	0.7852	0.0138
Kusar four way	24	0.3026	1.687	0.0089
Kusar four way	30	0.1921	0.4703	0.0183
Baghodrat four way	18	0.287	0.0323	0.0876

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