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Evaluation of Collapsibility Potential in Soil Layers Based on Practical Methods (Case study: Hir City-Ardabil Province)

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ABSTRACT:

Collapsible soils is one of the problematic soil because of complex mechanism collapse in them, the recognizing and analyzing effective parameters on phenomenon is so important. Collapsible soil is non- saturate soil, due to moisten and specifically loading, connection between soil particles become loose and finally suddenly destroying happen in soil layer. In this study, collapsible potential in soil layers of Hir city based on practical methods were evaluated. 16 specimens were collected in study area. Practical methods were divided to qualitative and quantitative criterions. In quantitative procedure, double odeometer test based on ASTM were performed. Results of this study showed that between qualitative methods there is not good agreement. Although, quantitative procedure proposed high risk in terms of collapsibility in soil layer.

Keywords: Soil collapsibility, Quantitative methods, Qualitative methods, Hir city, Ardebil.

1- Introduction

Collapsible soil is one of the problematic soil in construction projects and civil engineering. These soils can cause asymmetric settlement in soil layers under foundations and other damages in buildings and life lines. Collapsible soils in natural moisture condition have suitable strength and bearing capacity. While, saturation degree in collapsible soils because of increasing moisture go up, reducing in volume and void happen quickly between soil particles. Collapsible phenomenon occur due to losing connection strength between particles [1]. During to collapsibility, absorption of water and moisture by soil particles molecular force between aggregates because of difference mechanism such as softening, loss of capillarity force between particles for saturation decreases. This phenomenon can be occurred in soil layers with loose particle skeleton such as silty, fine sandy, sandy clay soils [2]. Properties of collapsible soil is including: high void ratio (more than 40%), low saturation degree (less than 60%), high silt content (between 30% and 90%) and quickly softening in soil particles (less than 1 minute) [3]. Collapsible soils can be observed in Aeolians (such as dune sand with low silt or clay content and high void ratio), residual soils and sediments due to muddy floods. Loess soils have collapsibility potential can be founded in desert areas in Iran, South of Kashan, Kerman province, Agh Ghala in Gorgan province, Masjid Soleiman city and Sivand in Fars province [4]. Nowadays, extensive researches have been performed for identifying collapsibility in soil layers. Clevenger in 1959 proposed a method based on maximum dry weigh [5], Gibbs and Bara in 1962 [6], Denisov in 1964 [7], Feda in 1966 [8] prepared a new criterions according to geotechnical properties of soil layers. Jennings and Knight in 1975 [3] were provided an experimental procedure with using double odeometer test based on ASTM D5333-03 [9]. In this research, consequences of two procedures were compared in Hir City about collapsibility potential in soil layers.

2. Materials and Methods

2.1. Materials

As mentioned above, in this research, collapsibility potential of soil layers in Hir city at Ardabil province in Iran was evaluated. For determining collapsibility 16 undisturbed samples were collected in different points of study area had been reported damages due to collapsible occurrence. Particle grading test was performed based on ASTM D421 [10] and ASTM D422 [11]. According to unified soils category method, type of samples taken generally is SM, SC and CL. Grading curve can be seen in Figure 1. Also, in Table 1 percentage of particles in samples separately was provided. Plasticity index and specific gravity (Gs) in specimens respectively were determined based on ASTM D4318-87 [12] and ASTM D854-87 [13]. Also, compaction test was carried out according to ASTM D698 [14]. Results can be seen in Table 2.

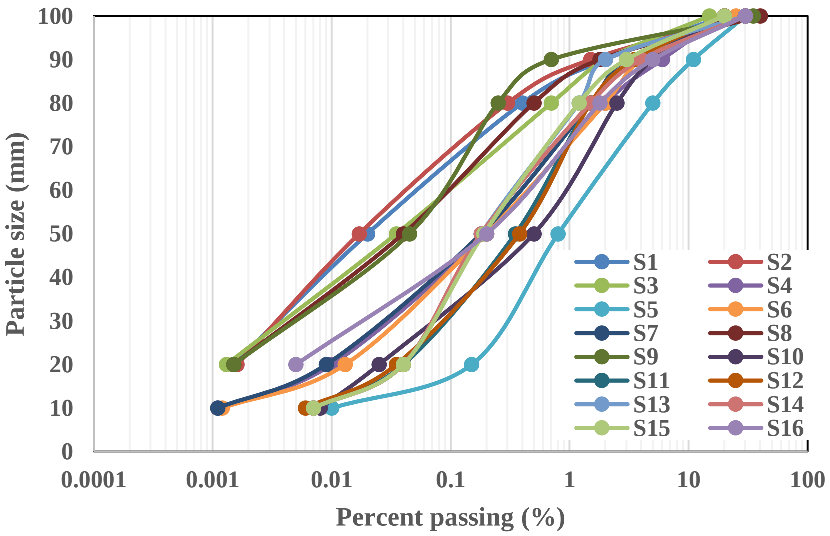

Fig.1. Grading curves of samples in study area.

Table 1. Percentage of particles in samples.

sample	% (gravel)	% (sand)	% (silt)	% (clay)
S(1)	3.75	32.5	41.25	22.5
S(2)	2.5	35	38.75	23.75
S(3)	5	38.75	31.25	25
S(4)	11.25	51.25	25	12.5
S(5)	20	63.75	11.25	5
S(6)	10	52.5	26.25	11.25
S(7)	7.5	55	25	12.5
S(8)	8.75	30	37.5	23.75
S(9)	1.25	35	41.25	22.5
S(10)	10	64	17.5	8.75
S(11)	6.25	70	16.25	7.5
S(12)	6.25	70	16.25	7.5
S(13)	7.5	52.5	31.25	8.75
S(14)	7.5	52.5	31.25	8.75
S(15)	7.5	52.5	31.25	8.75
S(16)	8.75	51.25	25	15

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Table 2. Geotechnical properties of samples in study area.

sample	PI	$\gamma_{dmax}(\text{gr/cm}^3)$	Wopt (%)	Gs	Unified soil Classification
S(1)	17	1.45	5.4	2.379	CL
S(2)	17	1.47	8.5	2.387	CL
S(3)	20	1.46	6.2	2.532	CL
S(4)	NP	1.49	5.3	2.374	SM
S(5)	NP	1.57	5.6	2.549	SM
S(6)	NP	1.45	5.4	2.427	SM
S(7)	10	1.49	7.7	2.626	SC
S(8)	25	1.59	5.9	2.67	CL
S(9)	18	1.71	5.7	2.697	CL
S(10)	10	1.53	8.1	2.537	SC
S(11)	7	1.59	7.1	2.536	SC-SM
S(12)	7	1.51	13.5	2.598	SC-SM
S(13)	13	1.59	7.1	2.573	SC
S(14)	13	1.58	11.7	2.544	SC
S(15)	13	1.58	8.7	2.556	SC
S(16)	16	1.73	7	2.623	SC

2.2. Methodology

In this study, for evaluating collapsibility in soil layers two criterions based on quantitative and qualitative were used. In first step, geotechnical properties of samples based on laboratory test determined and mentioned above. Then, with applying practical methods have been proposed by Priklonski [15], Clevenger, Gibbs and Bara, Denisov and Feda qualitative analyses were carried out. I second step, with using double odeometer test according to ASTM D53333-03, quantitative analyses were performed on specimens too. In final, results of both methodology were compared.

3. Results and discussion

3.1. Evaluation of collapsibility in soil layers based on qualitative method

3.1.1. Priklonski criterion

In this standard, viscosity index (K_D) for specimens with using Eq.1 were determined. While, K_D is less than 0.5, collapsibility risk is so high. In contrast, K_D value become more than 1, swelling potential can be seen in soil layers. Outcomes of collapsibility assessment in study area have been provided in Table.3. According to Table 3, it can be observed that collapsibility risk so high in study area.

$$K_D = \frac{w_0 - PL}{PI} \quad (1)$$

Table 3. Collapsibility evaluation based on Priklonski criterion.

sample	PI	K_D	Interpretation of Collapsibility
S(1)	17	-1.09	High risk
S(2)	17	-0.911	High risk
S(3)	20	-0.84	High risk
S(4)	NP	-	-
S(5)	NP	-	-
S(6)	NP	-	-
S(7)	10	-1.43	High risk
S(8)	25	-0.67	High risk
S(9)	18	-.085	High risk
S(10)	10	-.039	High risk
S(11)	7	-1.84	High risk
S(12)	7	-0.92	High risk
S(13)	13	-1.06	High risk
S(14)	13	-0.71	High risk
S(15)	13	-0.94	High risk
S(16)	16	-0.87	High risk

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3.1.2. Clevenger criterion

In this criteria, maximum dry unit weight (γ_{dmax}) for evaluating collapsibility in soil samples is used. So that, if γ_{dmax} was less than 1.28 gr/Cm^3, settlement happen in soil layer is probable. Whereas, this factor was more than 1.44 gr/Cm^3 collapsibility risk in soil is so low. In third position, if γ_{dmax} was between to mentioned number, settlement risk in soil have moderate risk. Outcomes of collapsibility assessment in study area have been provided in Table.4. As seen, based on this method collapsibility risk is so low.

Table 4. Collapsibility evaluation based on Clevenger criterion.

sample	γdmax (gr/cm3)	Interpretation of Collapsibility
S(1)	1.45	Low risk
S(2)	1.47	Low risk
S(3)	1.46	Low risk
S(4)	1.49	Low risk
S(5)	1.57	Low risk
S(6)	1.45	Low risk
S(7)	1.49	Low risk
S(8)	1.59	Low risk
S(9)	1.71	Low risk
S(10)	1.53	Low risk
S(11)	1.59	Low risk
S(12)	1.51	Low risk
S(13)	1.59	Low risk
S(14)	1.58	Low risk
S(15)	1.58	Low risk
S(16)	1.73	Low risk

3.1.3. Gibbs and Bara criterion

According to this rule, for assessing collapsibility in soil specimens, maximum dry unit weight and liquid limit (LL) is applied. In this method, it is assumed, if LL value in non-cemented soil was more than 20% and skeleton among soil particles become loose, collapsibility risk in soil is so high. With using diagrams in Figure 2 collapsible and non-collapsible soil con be recognized. With regard to Figure 2, it is observed more specimens in study area are non-collapsible.

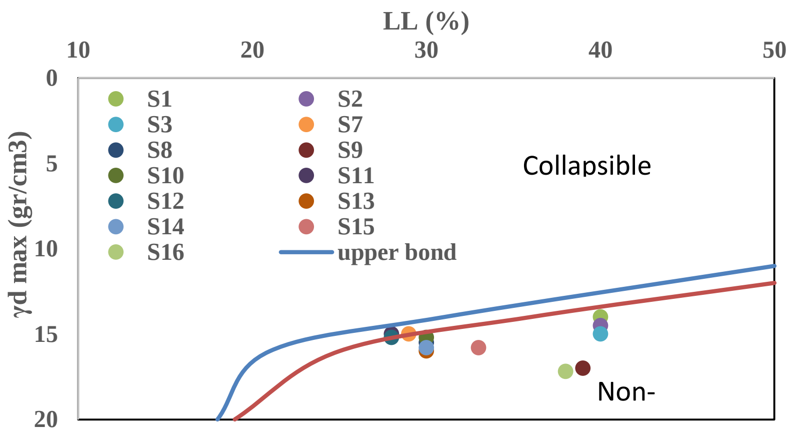

Fig.2. Results of collapsibility evaluation based on Gibbs and Bara method in study area.

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3.1.4. Denisov criterion

In this criteria, $\frac{e}{e_{ll}}$ ratio for analyzing collapsibility in soils is used. In mentioned ratio, e is natural void ratio, ell parameter is void ratio of soil liquid limit condition. Outcomes of evaluation according to present rule is observed in Table.5. Consequence of present criterion shows there is not collapsible soil in study area.

Table 5. Collapsibility evaluation based on Denisov criterion.

sample	e	ell	e/ell	Interpretation of Collapsibility
S(1)	0.641	0.975	0.675	Non- collapsible
S(2)	0.621	0.978	0.634	Non- collapsible
S(3)	0.734	1.08	0.674	Non- collapsible
S(4)	0.591	-	-	Non- collapsible
S(5)	0.622	-	-	Non- collapsible
S(6)	0.674	-	-	Non- collapsible
S(7)	0.766	0.84	0.911	Non- collapsible
S(8)	0.680	1.22	0.557	Non- collapsible
S(9)	0.574	1.05	0.545	Non- collapsible
S(10)	0.657	0.811	0.809	Non- collapsible
S(11)	0.596	0.684	0.871	Non- collapsible
S(12)	0.726	0.701	1.034	Non- collapsible
S(13)	0.620	0.874	0.708	Non- collapsible
S(14)	0.614	0.864	0.709	Non- collapsible
S(15)	0.620	0.869	0.713	Non- collapsible
S(16)	0.518	0.97	0.534	Non- collapsible

3.1.5. Feda criterion

Feda proposed a new criteria for evaluating collapsibility in soil layers according to Eq.2. In this rule, i_c factor is calculated. So that, if i_c and porosity degree respectively were more than 0.85 and 40%, collapsibility occurrence is probable. In below equation, Sr is saturation degree, m is mass of specimen. Results of collapsibility analysis in Hir City can be observed in Table 6. Similarity to previous both mentioned method, collapsibility risk is low.

$$i_c = \frac{\frac{m}{Sr} - PL}{PI} \tag{2}$$

Table 6. Collapsibility evaluation based on Feda criterion.

sample	Sr	ic	Interpretation of Collapsibility
S(1)	20	0.176	Non- collapsible
S(2)	33	0.1	Non- collapsible
S(3)	21	0.326	Non- collapsible
S(4)	21	-	Non- collapsible
S(5)	23	-	Non- collapsible
S(6)	20	-	Non- collapsible
S(7)	26	0.761	Non- collapsible
S(8)	23	0.152	Non- collapsible
S(9)	27	0.00617	Non- collapsible
S(10)	31	1.412	collapsible
S(11)	30	0.523	Non- collapsible
S(12)	48	1.16	collapsible
S(13)	30	0.2	Non- collapsible
S(14)	49	0.221	Non- collapsible
S(15)	36	0.243	Non- collapsible
S(16)	35	-0.0625	Non- collapsible

3.2. Evaluation of collapsibility in soil layers based on quantitative method

In second step, quantitative analysis of collapsibility in collected soil specimens with using double odeometer test according to ASTM D5333-0 was performed (Figure 3). As mentioned in previous parts, undisturbed specimens collected in study area. Results of test can be seen in Figure 4. Also, with combining criteria in Table 7 (Eq.3) and tests outcomes, collapsibility in samples evaluated. In difference with qualitative method, results of this study showed that in the Hir City collapsibility risk is moderate and so high.

$$CP = \frac{\Delta e}{1+e_0} (\%) \quad (3)$$

Table 7. Collapsibility evaluation based on double odeometer test criterion.

0.1< CP ≤ 2	Collapsibility risk is low
2< CP ≤ 6	Collapsibility risk is moderate
6 < CP ≤10	Collapsibility risk is high
CP > 10	Collapsibility risk is so high


Fig.3. Double odeometer apparatus in this study.

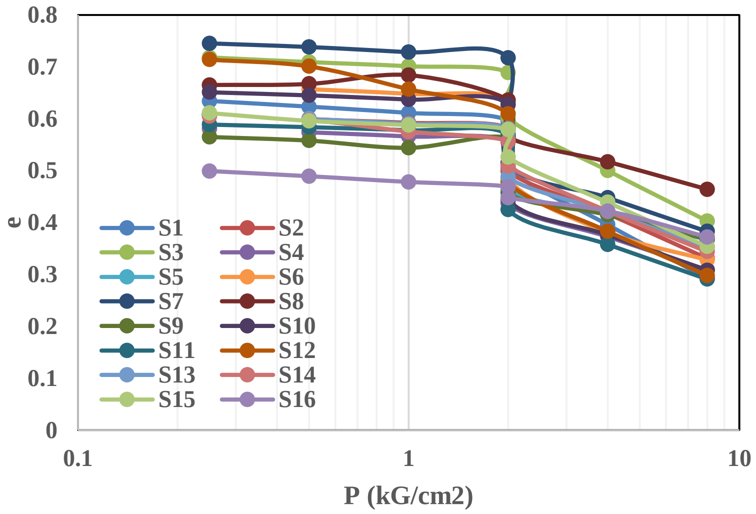

Fig.4. Results of double odeometer test on specimens study area.

Table 7. Collapsibility evaluation based on double odeometer test criterion.

sample	CP	Interpretation of Collapsibility
S(1)	5.54	Moderate collapsibility risk
S(2)	5.12	Moderate collapsibility risk
S(3)	5.01	Moderate collapsibility risk
S(4)	7.41	High collapsibility risk
S(5)	6.96	High collapsibility risk
S(6)	8.9	High collapsibility risk
S(7)	11.43	So high collapsibility risk
S(8)	4.22	Moderate collapsibility risk
S(9)	4.33	Moderate collapsibility risk
S(10)	10.98	So high collapsibility risk
S(11)	9.02	High collapsibility risk
S(12)	7.589	High collapsibility risk
S(13)	5.74	Moderate collapsibility risk
S(14)	2.97	Moderate collapsibility risk
S(15)	3.27	Moderate collapsibility risk
S(16)	1.38	Moderate collapsibility risk

4. Conclusions

Collapsible soil is one of the problematic soil in constructions and civil engineering. In this research, results of practical methods based on quantitative and qualitative theories for evaluating collapsibility of soils at the Hir City in Ardabil province were compared. Outcomes of present study describe as follows:

1- Quantitative procedure according to double odeometer test showed that approximately 16 of the undisturbed specimen have moderate to so high risk in terms of collapsibility. It should be noted samples have been taken at the depth of 1 meter from the ground in study area.

2- There is good agreement between quantitative procedure and Priklonski criteria in qualitative method.

3- Generally, there is not good adaption among qualitative rules results for evaluating collapsibility in soil layer. The reason could be that each one of empirical method separately correlate to one of the geotechnical parameters. This conditions is caused of unfitting results.

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4- Type of soil layer in study area was SM and SC according to unified method. Although, fine soils kind commonly observed silty and slity clay. This condition prepare collapsibility potential in soil layers in study area.

It is offered that for increasing accuracy between qualitative and quantitative method in collapsibility analysing, with performing more experimental and field tests and applying soft computing method, unreliability parameters recognized and detected.

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