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Identification of Collapsible Soil-A case Study

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Abstract. Soil is material formed due to weathering and erosion process of rocks. Water in contact with some type of soils cause problems in civil activities. These problems include swelling, dispersing and collapse of soil materials. Structures built on collapsible soils may settle if saturated under loading. Formations of collapsible soils are due to geologically deposit of silty or loamy material such as loess which are loosely cemented by calcium carbonate and is mainly deposited by the wind. Field observations and laboratory tests can be useful to identify problematic soils. Some properties of soils are helpful to estimate collapsibility potential of soils. In this present paper a case study of Project in Northern part of India has been considered to evaluate the geotechnical properties of soil materials. Laboratory Investigations such as liquid limit, plastic limit, plasticity index, moisture content, dry density and one dimensional consolidation tests on 19 undisturbed soil samples collected at various depths from two different locations were carried out. Most of the samples were Silty Sand and were Non Plastic in nature as per IS Classification of soils. Identification of collapsible nature of soil was determined by conducting Double Oedometer tests. Void ratios arrived by conducting Double Oedometer tests were used for measuring collapse potential. The severity of foundation problems associated with the collapsible soils have been correlated with the collapse potential, which shows that all soil samples falls under moderate trouble nature.

Keywords: Collapsible soils; Liquid Limit; Plastic Limit; Dry Density; Water Content; Oedometer Test**;**.

1 Introduction

There are many types of problematic soils, some of the most noteworthy being swelling clay, dispersive soils and collapsible soils. Collapsible soils are found throughout the world in soil deposits. The most common types of natural collapsible soil are: water (alluvial), wind (aeolian), and gravity (colluvial) deposits, and residual (from extensive weathering of parent rock) soils. Typically these soils are found in arid or semiarid regions. Soils such as loess and certain wind-blown silts may have the potential to collapse.

"Collapsible soils are defined as any unsaturated soil that goes through a radical rearrangement of particles and greatly decreases in volume upon wetting, additional loading or both"

These soils are usually capable of sustaining substantial high-applied vertical stress in their unsaturated state without significant volume change but when wetted, undergo rapid and large reduction in volume. Collapse is believed to occur when the particle-to-particle bonding is destroyed by wetting with or without additional loading. Collapse on saturation normally takes only a short period of time.

Their mineralogy spans a wide range but particles usually varying between sand and clay sizes. Capillary water, clay minerals, calcium carbonate and other soluble salts have been argued to play a role in the formation of bonding between soil particles, providing the initial stability in these collapsible soils. However, wetting, eliminates this bonding and sudden restructuring occurs.

Foundations that are constructed on such soils may undergo large & sudden settlement if & when the soil under them becomes saturated with an unanticipated supply of moisture and have resulted into huge loses (economic and lives), considerable structural damage etc. Collapse is usually triggered either naturally through flooding, groundwater rise, or artificially by human activity. Human activity can be either via unintentional poor drainage control (e.g. broken water or sewer lines, landscape irrigation, poor surface drainage, roof runoff, etc.).

The scope of this paper is to find out Collapse Potential of tested soils by using void ratio at different stress levels arrived by conducting Double Oedeometer tests on Soil samples.

2 Identification Of Collapsible Soils

A geotechnical engineer should identify the soils that may collapse and to determine the amount of collapse that might occur. The identification and prediction of soil collapse have proven difficult because no single criterion can be applied to all collapsible soils.

2.1 Laboratory Testing

The following laboratory investigations were carried out on 19 undisturbed soil samples collected from two bore holes as per under mentioned Bureau of Indian Standards:

- Mechanical Analysis	IS: 2720 (Part IV)
- Atterberg Limits	IS: 2720 (Part V)
- Insitu Density and Moisture Content tests	IS: 2720 (Part XXIX)
- Double Oedeometer tests	as per standard procedure

Classification of these soil samples was done as per IS: 1498

3 Case Study

In this present paper a case study of Project in Northern part of India has been considered to evaluate the Geotechnical Properties of soil material. The present paper is based on the tests result of Double Oedometer tests on the 19 undisturbed soil samples collected from two bore holes at different locations. Laboratory investigations such as liquid limit, plastic limit, plasticity index, moisture content, dry density and one dimensional consolidation tests on 19 soil samples were carried out.

Table 1: General properties of soil samples of Bore Hole-1 and Bore Hole-2

Soil Sam. no.	Depth (meter)	Soil Classification	PL (%)	PI (%)	LL (%)	w (%)	γ_d (gm/cm3)
			BORE HOLE - 1				
1/1	3.00 - 3.35	SM	Non- Plastic		26.6	17.4	1.36
1/2	9.00 - 9.42	SM	Non- Plastic		27.0	16.1	1.41
1/3	15.00-15.40	SM	Non- Plastic		27.5	20.1	1.37
1/4	27.00 - 27.33	SM	Non- Plastic		27.1	18.8	1.35
1/5	60.30 - 60.60	SM	Non- Plastic		25.0	20.8	1.50
1/6	78.30 - 78.60	SM	Non- Plastic		25.5	19.1	1.65
1/7	84.00 - 84.30	SM	Non- Plastic		26.2	23.1	1.59
1/8	96.00 - 96.30	SM	Non- Plastic		24.9	18.3	1.62
1/9	102.30 - 102.6	ML	Non- Plastic		23.1	19.7	1.59
			BORE HOLE - 2				
2/1	3.00 - 3.50	ML	Non- Plastic		25.2	13.0	1.59
2/2	6.00 - 6.50	CL	Non- Plastic		27.7	14.1	1.56
2/3	21.00 - 21.50	CL	19.1	15.8	26.8	15.8	1.43
2/4	36.00 - 36.30	SM	Non- Plastic		24.5	9.4	1.41
2/5	39.00 - 39.30	SM	Non- Plastic		25.1	14.2	1.35
2/6	42.00 - 42.30	SM	Non- Plastic		24.2	11.9	1.33
2/7	45.00 - 45.30	SM	Non- Plastic		23.8	9.39	1.41
2/8	48.00 - 48.30	ML	Non- Plastic		24.5	12.0	1.34
2/9	51.30 - 51.60	ML	Non- Plastic		23.9	11.0	1.35
2/10	57.00 - 57.30	ML	Non- Plastic		24.4	12.0	1.34

3.1 Determination of Collapse Potential by Double Oedometer Tests

The severity of foundation problems associated with the collapsible soils have been correlated with the collapse potential 'CP' by Jennings & Knight (1975). They were summarized by Clemence & Finbarr (1981) and are given in Table-2

Table 2. Collapse Potential percentage as an indication of potential severity

Collapse Potential (%)	0-1	1-5	5-10	10 - 20	Over 20
Severity of problem	No problem	Moderate trouble	Trouble	Severe trouble	Very severe trouble

Two types of oedometer tests can be employed to determine collapse potential: the single-oedometer test and the double-oedometer test. The advantage of the double-oedometer test is that through a single test one can obtain a large amount of data without repeating single oedometer tests at different stress levels.

In the present case, Double Oedometer tests were conducted on 19 soil samples collected from Bore Hole-1 andBore Hole -2. In Double Oedometer tests, two identical samples are placed in oedometers; one tested at in-situ natural moisture content and the other is fully saturated before the test begins and then subjected to identical loading of 0.25, 0.5, 1, 2 and 4 kg/cm^2. Two stress versus strain curves are generated. The difference between the compression curves is the amount of deformation that would occur at any stress level at which the soil get saturated. The collapse potential can be determined at any required stress level by the following two equations.

Collapse Potential (I_e) can be defined by Abelev (1948)

$$CP\ (I_e) = \frac{\Delta e_c}{1+e_1} \qquad (1)$$

Where:
Δe_c: Change in void ratio resulting from saturation
e_1 : Void ratio just before saturation

While Jennings and Knight (1975), recommended to calculate the collapse potential according to the following equation:

$$CP(I_e)=\frac{\Delta e_c}{1+e_1} \qquad (2)$$

Where:
Δe_c: Change in void ratio resulting from saturation
e_1 : Natural void ratio

In present case, the equation defined by Abelev (Eq 1) has been used to find out Collapse Potential. The results of Double Oedometer tests for 9 soil samples of Bore Hole-1 are shown in Table-3 and 10 soil samples of Bore Hole-2 are shown in Table-4.

Table 3. Results of Double Oedometer tests of Bore Hole-1

Sam. No.	Depth (m)	Void ratio	Pressure (kg/cm2)					
			0	0.25	0.50	1	2	4
1/1	3.00 - 3.35	e_{sat}	0.600	0.594	0.586	0.574	0.567	0.562
		e_{nmc}	0.613	0.609	0.604	0.597	0.589	0.577
		CP%	0.81	0.93	1.12	1.44	1.38	0.95
		Severity of Collapse (1.44)				Moderate trouble		
1/2	9.00 - 9.42	e_{sat}	0.520	0.510	0.499	0.484	0.471	0.458
		e_{nmc}	0.533	0.529	0.518	0.507	0.492	0.474
		CP%	0.85	1.24	1.25	1.53	1.41	1.09
		Severity of Collapse (1.53)				Moderate trouble		
1/3	15.00-15.40	e_{sat}	0.535	0.526	0.515	0.501	0.493	0.487
		e_{nmc}	0.547	0.544	0.536	0.526	0.517	0.508
		CP%	0.78	1.17	1.37	1.64	1.58	1.39
		Severity of Collapse (1.64)				Moderate trouble		
1/4	27.00 - 27.33	e_{sat}	0.569	0.562	0.550	0.535	0.520	0.504
		e_{nmc}	0.575	0.573	0.566	0.556	0.540	0.520
		CP%	0.38	0.70	1.02	1.35	1.30	1.05
		Severity of Collapse (1.35)				Moderate trouble		
1/5	60.30 - 60.60	esat	0.506	0.498	0.486	0.473	0.461	0.450
		enmc	0.527	0.522	0.514	0.504	0.494	0.484

		CP%	1.38	1.58	1.85	2.06	2.21	2.29
		Severity of Collapse (2.29)				Moderate trouble		
1/6	78.30 - 78.60	e_{sat}	0.515	0.509	0.498	0.485	0.472	0.460
		e_{nmc}	0.527	0.525	0.518	0.508	0.494	0.480
		CP%	0.79	1.05	1.32	1.53	1.47	1.35
		Severity of Collapse (1.53)				Moderate trouble		
1/7	84.00 - 84.30	e_{sat}	0.509	0.502	0.490	0.477	0.465	0.455
		e_{nmc}	0.517	0.514	0.508	0.497	0.487	0.477
		CP%	0.53	0.79	1.19	1.34	1.48	1.49
		Severity of Collapse (1.49)				Moderate trouble		
1/8	96.00 - 96.30	e_{sat}	0.513	0.508	0.498	0.486	0.474	0.462
		e_{nmc}	0.521	0.518	0.510	0.501	0.490	0.480
		CP%	0.53	0.66	0.79	1.00	1.07	1.22
		Severity of Collapse (1.22)				Moderate trouble		
1/9	102.3 - 102.6	e_{sat}	0.515	0.507	0.496	0.484	0.473	0.463
		e_{nmc}	0.527	0.522	0.512	0.502	0.492	0.481
		CP%	0.79	0.99	1.06	1.20	1.27	1.22
		Severity of Collapse (1.27)				Moderate trouble		

e_{sat}- void ratio at saturation, e_{nmc}- Void ratio at natural moisture content, CP-collapse potential

Table 4. Results of Double Oedometer tests of Bore Hole-2

Sam. No.	Depth (m)	Void ratio	Pressure (kg/cm2)					
			0	0.25	0.50	1	2	4
2/1	3.00 - 3.50	e_{sat}	0.499	0.490	0.471	0.448	0.428	0.411
		e_{nmc}	0.527	0.512	0.501	0.486	0.471	0.455
		CP%	1.83	1.46	2.00	2.56	2.92	3.02
		Severity of Collapse (3.02)				Moderate trouble		
2/2	6.00 - 6.50	e_{sat}	0.504	0.490	0.470	0.449	0.420	0.391
		e_{nmc}	0.515	0.501	0.489	0.475	0.457	0.433
		CP%	0.73	0.73	1.28	1.76	2.54	2.93
		Severity of Collapse (2.93)				Moderate trouble		
2/3	21.00 - 21.50	e_{sat}	0.533	0.518	0.499	0.476	0.457	0.434
		e_{nmc}	0.542	0.533	0.516	0.495	0.471	0.448
		CP%	0.58	0.98	1.12	1.27	0.95	0.97
		Severity of Collapse (1.27)				Moderate trouble		
2/4	36.00 - 36.30	e_{sat}	0.550	0.543	0.532	0.518	0.511	0.505
		e_{nmc}	0.556	0.552	0.546	0.540	0.532	0.525
		CP%	0.39	0.58	0.91	1.43	1.37	1.31
		Severity of Collapse (1.43)				Moderate trouble		
2/5	39.00 - 39.30	e_{sat}	0.563	0.557	0.544	0.530	0.518	0.508
		e_{nmc}	0.575	0.571	0.566	0.557	0.548	0.542
		CP%	0.76	0.89	1.40	1.73	1.94	2.20
		Severity of Collapse (2.20)				Moderate trouble		
2/6	42.00 - 42.30	e_{sat}	0.563	0.556	0.544	0.531	0.519	0.510
		e_{nmc}	0.569	0.565	0.560	0.555	0.544	0.532
		CP%	0.38	0.58	1.03	1.54	1.62	1.44
		Severity of Collapse 1.62)				Moderate trouble		

2/7	45.00 - 45.30	e_{sat}	0.550	0.547	0.536	0.522	0.510	0.500
		e_{nmc}	0.563	0.559	0.552	0.545	0.538	0.531
		CP%	0.83	0.77	1.03	1.49	1.82	2.02
	Severity of Collapse (2.02)					Moderate trouble		
2/8	48.00 - 48.30	e_{sat}	0.579	0.556	0.544	0.534	0.519	0.499
		e_{nmc}	0.587	0.574	0.565	0.553	0.533	0.506
		CP%	0.50	1.14	1.34	1.22	0.91	0.46
	Severity of Collapse (1.34)					Moderate trouble		
2/9	51.30 - 51.60	e_{sat}	0.581	0.558	0.547	0.536	0.521	0.500
		e_{nmc}	0.587	0.574	0.565	0.553	0.533	0.512
		CP%	0.38	1.02	1.15	1.09	0.78	0.79
	Severity of Collapse (1.15)					Moderate trouble		
2/10	57.00 - 57.30	e_{sat}	0.590	0.573	0.550	0.534	0.523	0.509
		e_{nmc}	0.600	0.592	0.578	0.565	0.552	0.538
		CP%	0.63	1.19	1.77	1.98	1.87	1.89
	Severity of Collapse (1.98)					Moderate trouble		

e_{sat}- void ratio at saturation, e_{nmc}- Void ratio at natural moisture content, CP-collapse potential

A typical void ratio (e) versus log p curves for sample number 2/2 has been shown in Figure 1.

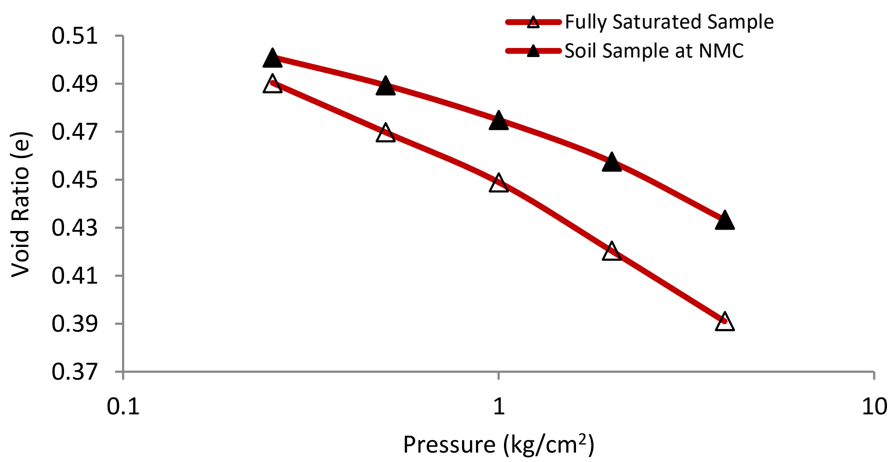

Fig. 1. Void ratio (e) versus log p curves for sample number 2 / 2

4 Discussion

The grain size analysis of 9 soil samples from BH-1 and 10 soil samples from BH-2 indicate that most of the tested samples have predominately mixture of fine sand, silt and followed by clay.

Based on mechanical analysis, out of 19 soil samples, 12 soil samples fall under SM (Silty Sand) group and 5 soil samples fall under ML (Silt with low Plasticity) and 2 soil samples fall under CL (Clay with low Plasticity) groups as per BIS soil classification.

Value of In-situ density and natural moisture content for tested soil samples from both the bore holes ranges from 1.35 g/cc to 1.65 g/cc and 23.1% to 27.7% respectively.

It is seen from tests results of Double Oedometer tests as presented in Table-2 in general that the vertical displacement of fully saturated samples is higher than the samples tested at natural moisture condition under identical loading conditions. All of the tested samples indicated appreciable vertical displacement in saturated conditions indicating that the severity of collapse in all soil samples falls under moderate trouble nature (Collapse Potential is within 1-5 range as given in Table-2).

5 Conclusion

It is concluded from the test results of Double Oedometer Tests on soil samples of two boreholes that in both the boreholes all the soil samples fall under moderately trouble nature.

Several techniques for predicting and classifying collapse have been proposed. They are grouped into indirect correlations, laboratory, geophysical, and field loading methods. Although laboratory methods are seen to be best for describing these soils, it is argued that no single testing method is adequate to fully describe collapse in any soil. Nevertheless, collapse testing should be site specific and anticipatory.

6 References

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