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Prediction of Collapsible Behavior of Red Soils

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ABSTRACT: *Red soils make the construction of foundations extremely difficult in its natural state. It may cause high differential movements in structures through collapse settlement on saturation. This phenomenon is primarily related to the open structure of red soils. Identifying these soils in the field can reduce the risk of distress usually reported in buildings and roads. These soils can withstand relatively high pressure without significant change in volume on drying, by wetting they are suspected with sudden reduction in volume.*

In this context an attempt was made on 6 red soils to relate the collapsibility behavior of the soils by considering initial water content, dry density, saturation moisture content, liquid limit, void ratios as parameters and compared with various exciting collapsibility theories.

KEYWORDS: *Red soils, Geotechnical characterizations, Collapsibility behavior.*

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I. INTRODUCTION:

Collapsible soils may be defined as unsaturated soils that can sustain substantially high applied vertical stresses without showing significant change in volume. Collapsible soils consist of loose, dry, low-density materials that collapse under addition of water or excessive loading. Soil collapse occurs when the land surface is saturated at depths greater than those reached by typical events. This saturation eliminates the clay bonds holding the soil grains together. Similar to expansive soils, collapsible soils result in structural damage such as cracking of the foundation, floors, and walls in response to settlement.

Many researchers have been proposed in the literature relating the collapsibility to conventional soil properties (Clevenger, 1958; Denisov. 1951; Feda. 1966; Gibbs and Holland. 1960; Haeri and Garakani. 2012; Haeri et al. 2012a; Haeri et al. 2012b; Handy. 1973; Nuntasarn. 2011; Popescu and Coric. 1998; Zhu and Chen 2009; Haeri et al. 2014; Garakani et al. 2015; Haeri et al. 2015c;

In the present analysis 6 red soils from Vishakhapatnam region in north coastal districts of Andhra Pradesh were collected and tested for their geotechnical characterization. Based on these values, their collapsibility behavior has been verified.

II. MATERIAL AND METHODS:

To study the geotechnical characterization of red soils in Visakhapatnam region, the soil samples were collected at a depth of 1.0 – 1.5m from the ground level and the collected samples were dried and subjected for geotechnical characteristics such as grain size distribution, plasticity, compaction and strength as per IS 2720.

III. TESTS & RESULTS:

3.1) Grain Size Distribution:

The collected red soil samples were dried and tested for grain size distribution by performing dry sieve analysis (IS 2720-Part 4-1985), wet sieve analysis and the results are shown in table1.

Table 1: GRADATION PROPERTIES OF RED SOIL:

Location/Property	BHIMILI	YANDADA	GAJUWAKA	MAHARANIPETA	ALLIPURAM	CHINNAGADILI
Gravel (%)	0	0	0	0	0	0
Sand (%)	56	60	80	81	76	71
Fines (%)	44	40	20	19	24	29
Silt (%)	28	26	12	15	20	18
Clay (%)	16	14	8	4	4	5

Liquid Limit(%)	34	32	30	22	22	23
Plastic Limit (%)	20	20	20	17	18	18
Plasticity Index (I_p)	14	12	10	5	4	5
IS Classification	SC	SC	SC	SM-SC	SM	SM-SC
OMC (%)	12.5	12.2	12.2	8.7	8.8	8.6
MDD(g/cc)	1.80	1.80	1.80	1.87	1.88	1.86
Specific Gravity (G)	2.67	2.67	2.66	2.66	2.65	2.66
Shear Parameter At OMC						
C. (t/m^2)	2.5	2.0	2.0	1.5	1.4	1.5
φ.. (degrees)	28	26	28	30	30	29
Shear Parameter At Saturation						
C. (t/m^2)	1.2	1.0	0.7	0.8	0.5	0.8
φ.. (degrees)	24	22	23	24	22	23

- From the test result it is identified that all these soil are coarse grained dominated by sand particles which are in the range of (56% - 81%), fines (silts and clays) are in the range of (19% - 44%) out of which clay particle are in the range of 4 – 16%.
- Consistency characteristics like liquid limit (W_1) are in the range of 22 – 34% plastic limit is in the range of 17 – 20% and plasticity Index is in the range of 4 – 14%.
- Compaction characteristics such as OMC is in the range of 8.6 – 12.5% and MDD is in the range of 1.80 – 1.88 g/cc. Specific gravity is in the range of 2.65 – 2.67.
- Based on IS classification these are classified under SC, SM-SC, SM soils.
- These soils exhibited high strength in terms cohesion as 1.4 – 2.5t/m^2 and angle of shearing resistance (φ) as 26^0 – 30^0, on saturation these values are dropped to 0.5 – 1.2 t/m^2 and 22 – 24^0 respectively.

3.2 Exciting methods of Estimation of Collapsible Potential:

3.2.1 Denisov's (1951):

Uses the coefficient of subsidence, which is the ratio of the void ratio at the liquid limit to the in situ void ratio.

Denisov's coefficient of subsidence (k) = void ratio at liquid limit / natural void ratio.

Collapsibility Factor (k) = $\frac{e_l}{e_n}$

Where, e_l = void ratio at liquid limit; e_n = Void ratio at remolded water content corresponding to their dry densities.

If, K= 0.5 – 0.75: highly collapsible soil; If, K= 1.0: non collapsible loam; If, K= 1.5 – 2.0: non collapsible soil;

3.2.2 Clevenger (1956):

Proposed the criterion for collapsibility in terms of dry unit weight, if the dry density is less than 12.6 KN/m^3, then the soil is liable to undergo significant settlement and if the dry density is larger than (14.1kN/m^3), soils are capable of supporting the assigned loads.

3.2.3 Gibbs (1961):

Proposed a measure of collapse potential, which is displayed in graphical form, It is the ratio of the water content at full saturation to the liquid limit.

Collapsible ratio (R) = $\frac{w_{sat}}{w_L}$

Where, w_{sat} = saturation water content; w_L = Liquid limit

R < 1 (Non – collapsible soils); R > 1 (Collapsible soils);

3.2.4 Handy (1973):

1. Clay content of less than 16 percent had a high probability for collapse;
2. Clay content of between 16 and 24 percent were probably collapsible;
3. Clay content between 25 and 32 percent had a probability of collapse of less than 50 percent;
4. Clay content which exceeded 32 percent was non-collapsible.

Soils in which the ratio of liquid limit to saturation moisture content was less than unity were collapsible, while if it was greater than unity they were safe.

3.3Estimation of Collapsible potential of red soils:

To estimate the collapsible potential of red soils of varying geotechnical characterization the following properties have been computed and listed below:

Table 2: Characteristics of Red soils at various consistencies

(Υ_d) g/cc	1.30	1.40	1.50	1.60	1.70	1.80	1.90
(e_n) %	1.05	0.90	0.77	0.66	0.56	0.48	0.40
(W_{sat})	40	34	29	25	21	18	15
(Υ_{sat}) g/cc	1.81	1.88	1.94	2.00	2.06	2.12	2.18
(Υ') g/cc	0.79	0.88	0.94	1.00	1.07	1.12	1.19

3.4 DENISOV'S Method:

By using the above data Denisov's coefficient of Subsidence (K) = e_l/e_n is calculated and shown below:

Table 3: DENISOV'S COEFFICIENT OF SUBSIDENCE (K):

	Dry Densities (g/cc)						
(W_L)%	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**	**1.9**
21	0.53	0.62	0.73	0.85	1.0	1.17	1.40
22	0.56	0.66	0.77	0.89	1.05	1.23	1.48
23	0.58	0.68	0.79	0.93	1.09	1.27	1.53
24	0.61	0.71	0.83	0.97	1.14	1.33	1.60
25	0.64	0.75	0.87	1.02	1.20	1.40	1.68
26	0.66	0.77	0.90	1.05	1.23	1.44	1.73
27	0.69	0.80	0.94	1.09	1.29	1.50	1.80
28	0.71	0.83	0.98	1.14	1.34	1.56	1.88
29	0.73	0.86	1.0	1.71	1.38	1.60	1.93
30	0.76	0.89	1.04	1.21	1.43	1.67	2.0
31	0.79	0.92	1.08	1.26	1.48	1.73	2.08
32	0.81	0.94	1.10	1.29	1.52	1.77	2.13
33	0.84	0.98	1.14	1.33	1.57	1.83	2.2
34	0.87	1.01	1.18	1.38	1.63	1.90	2.28
35	0.89	1.03	1.21	1.41	1.66	1.94	2.33

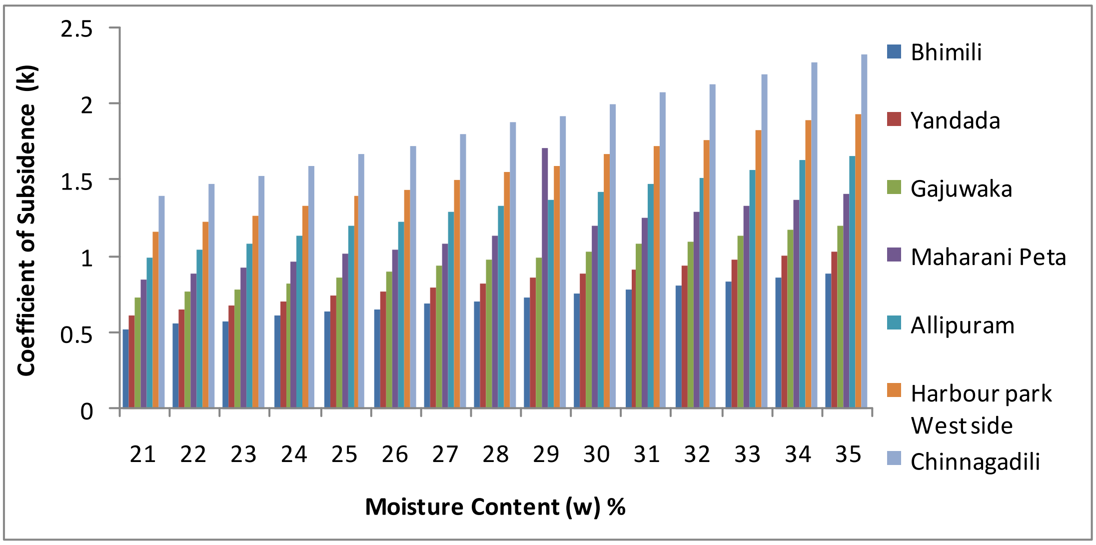

Fig 1. Collapsibility Factor (k)

From the above data the following identifications are made:

- Soils existing at low dry densities (1.3 g/cc to 1.5 g/cc) exhibit the high risk of collapsibility (k = 0.5 to 0.75) and soil exhibiting high dry densities greater than 1.7 g/cc and at their MDD are free from the risk of collapsibility (k = 1.5 to 2.5)
- Soil exhibits with their dry densities in between (1.5 to 1.7 g/cc) will exhibit with moderate collapsibility soils (k = 0.75 to 1.5).
- Soils with low values of liquid limit i.e., < 25 % are exhibiting high risk of collapsibility, and soils with high liquid limit > 35 % free from collapsibility.

3.5 GIBBS METHOD:

By using the above data Gibbs collapsible ratio (R) = w_{sat} / w_L is calculated and shown below:

Table 4: GIBBS COLLAPSIBLE RATIO (R):

(W_l)	**Υ_d**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**	**1.9**
%	**W $_{sat}$**	**40**	**34**	**29**	**25**	**21**	**18**	**15**
21	1.91		1.62	1.38	1.19	1.0	0.86	0.71
22	1.82		1.55	1.32	1.14	0.95	0.82	0.68
23	1.74		1.48	1.26	1.09	0.91	0.78	0.65
24	1.67		1.42	1.21	1.04	0.88	0.75	0.63
25	1.60		1.36	1.16	1.0	0.84	0.72	0.60
26	1.54		1.31	1.12	0.96	0.81	0.69	0.58
27	1.48		1.26	1.08	0.93	0.78	0.67	0.56
28	1.43		1.21	1.04	0.89	0.75	0.64	0.54
29	1.38		1.17	1.0	0.86	0.72	0.62	0.52
30	1.33		1.13	0.97	0.83	0.7	0.60	0.50
31	1.29		1.10	0.94	0.81	0.67	0.58	0.48
32	1.25		1.06	0.91	0.78	0.66	0.56	0.47
33	1.21		1.03	0.88	0.76	0.64	0.55	0.45
34		1.18	1.0	0.85	0.74	0.62	0.53	0.44
35		1.14	0.97	0.83	0.71	0.60	0.51	0.43

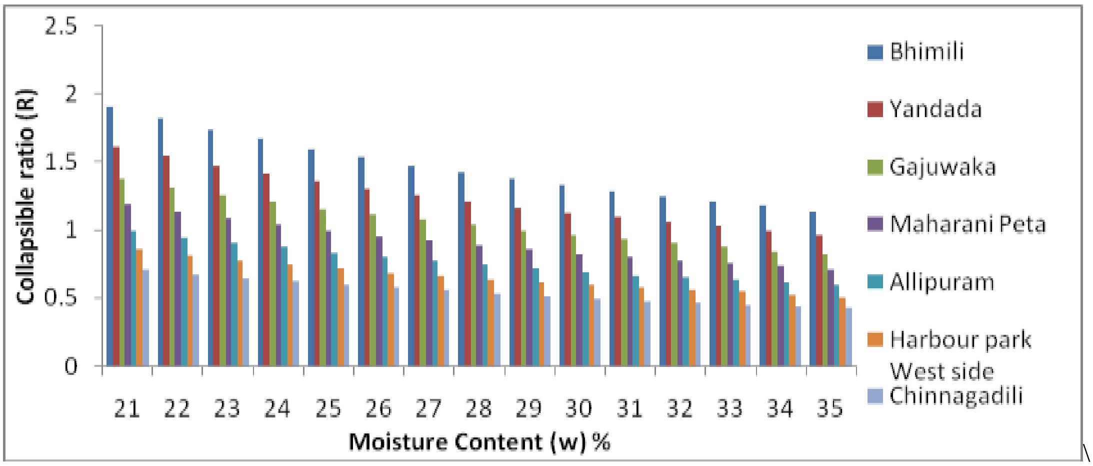

Fig 2. Collapsible Ratio

From the above data the following identifications are made:

1. Soils exhibiting at high densities greater than 1.6 g/cc and values nearing to their maximum dry densities are free from collapsibility i.e., ratio (R) less than 1.
2. Soils having high liquid limit greater than 30% are showing less potential for collapsibility.
3. Soils exhibiting at low saturation moisture contents i.e., water content in between OMC and plastic limit will free from collapsibility.
4. Soils exhibiting at high saturation moisture content i.e., deficiency in moisture content with respect to their natural/ remolded water contents will experience collapsibility.
5. Soils having high liquid limit will have much tolerability against collapsibility.

3.6 Holtz and Hilf METHOD:

HOLTZ and HILF identified collapsibility takes place when $w_{sat} > w_L$ is calculated and shown below:
From the above test data the following data was listed in the table to express the collapsibility.

Table 5: HOLTZ AND HILF COLLAPSIBILITY:

Dry Density g/cc	1.3	1.4	1.5	1.6	1.7	1.8	1.9
Moisture Content (W_l)	40	34	29	25	21	18	15
21	C	C	C	C	C	NC	NC
22	C	C	C	C	NC	NC	NC
23	C	C	C	C	NC	NC	NC
24	C	C	C	C	NC	NC	NC
25	C	C	C	C	NC	NC	NC
26	C	C	C	NC	NC	NC	NC
27	C	C	C	NC	NC	NC	NC
28	C	C	C	NC	NC	NC	NC
29	C	C	C	NC	NC	NC	NC
30	C	C	NC	NC	NC	NC	NC
31	C	C	NC	NC	NC	NC	NC
32	C	C	NC	NC	NC	NC	NC
33	C	C	NC	NC	NC	NC	NC
34	C	C	NC	NC	NC	NC	NC
35	C	NC	NC	NC	NC	NC	NC

C – Collapsible soil; NC – Non Collapsible soil

- Soils exhibiting dry densities less than 1.6g/cc shows collapsible behavior and greater than 1.6 g/cc exhibited non collapsible.
- Red soils with high liquid limit greatest than 30 and high dry densities 1.6g/cc exhibited non collapsibility.

Handy (1973):
In the present study red soils with clay content less than 16 % exhibited low liquid limit values and low dry densities values.
These soils exhibited and tending to be exhibited collapsible behavior.

Clevenger (1956):
In the present study red soils with dry densities in between 1.3 – 1.4 exhibited void ratios in the range 0.92 - 1.0, dry densities in between 1.4 – 1.6 g/cc is 0.9-0.67 and greater than 1.6 – 1.9 g/cc is 0.6 -0.4 respectively. Therefore the dry density is less than 1.6 g/cc is liable to undergo significant settlements which are under collapsibility.

IV. CONCLUSION:

By observing results from the consistency, grain size distribution and compaction test data the following conclusions have drawn:

Collapsibility occurs at low percentages of clay contents (less than 10), low dry densities (less than 1.6 g/cc), low moisture contents and low liquid limits (less than 25%) in red soils.

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