ROLE OF INDEX PROPERTIES IN PREDICTING COLLAPSIBLE BEHAVIOUR OF RED SOILS

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ABSTRACT: Soil collapse takes place when dry soil mass inundated with water. Which increases moisture content in the soil mass. This increased moisture causes breaking of chemical and physical bonds between the soil particles which allow the structure of the soil to collapse. These soils show relatively high apparent strength in their dry state and sudden loss of strength on wetting. Collapse characteristics contribute various problems to infrastructures that are constructed on red soils. Identifying these soils with respect to the degree of collapsibility can reduce the risk of distress when structures founded on these soils. In this study to understand the geotechnical properties of red soils which causes collapsibility. An attempt is made with 10 red soils from various locations with the geotechnical characteristics to relate the collapsibility has been studied by considering parameters like water content, dry density, saturation moisture content, void ratio and porosity etc. The degree of collapsibility of these soils are explained with existing models.

INDEX TERMS: Collapse, Geotechnical Characteristics, Parameters.

I. INTRODUCTION:

Collapsible soil are open structured dry soils, on saturated get collapse through rearrangement of particles and create huge loss of durability of the structures due to differential settlement of foundation. These failures cause high damage to infrastructure facilities. The collapsibility of these soils have been focused by understanding their origin, existence description with respect to geological and geo-morphological structural bonds the above characteristics can indirectly verified by understanding the index properties like ,grain size distribution percentage and Atterberg limits, in-suite dry density, moisture content, degree of saturation etc., these index properties will associated with collapsible behavior of soil. Researches like Denisov's.(1951); Feda.(1966); Gibbs and Holland. (1960) etc., have been utilized these index properties in understanding the collapsible behavior though various models which are listed below:

1.2 Exciting methods of Estimation of Collapsible Potential:

1.2.1 Denisov's (1951):

Uses the coefficient of subsidence for identifying collapsible behavior.

Denisov's coefficient of subsidence (k) = void ratio at liquid limit / natural void ratio = $\frac{e_l}{e_n}$

Where e_n = Void ratio at remolded water content corresponding to their dry densities.

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

1.2.2 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.

1.2.3 Gibbs (1961):

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

Collapsible ratio (R) = $\frac{w_{sat}}{w_L}$: R < 1 (Non – collapsible soils); R > 1 (Collapsible soils);

1.2.4 Handy (1973):

- Clay content of less than 16 percent had a high probability for collapse;
- Clay content of between 16 and 24 percent were probably collapsible;
- Clay content between 25 and 32 percent had a probability of collapse of less than 50 percent;
- 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.

The present investigation aim at understanding the collapsible behavior of red soils by considering various index properties at their compacted conditions.

2. MATERIALS, TESTS & RESULTS:

To study the geotechnical characteristics 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.

TABLE 1: GEOTECHNICAL PROPERTIES OF RED SOILS (SC) OF VISAKHAPATNAM REGION:

Property	Values
Gradation Properties	
Gravel (%)	0
Sand (%)	56-80
Fines (%)	20 – 44
Silt (%)	12 – 28
Clay (%)	8 – 16
Specific Gravity (G)	2.6 – 2.67
Index Properties	
Liquid Limit (%) (W_L)	25 – 34
Plastic Limit (%) (W_P)	18 – 20
Plasticity Index (I_p)	7 – 14
IS Classification	SC
Compaction Characteristics	
Optimum Moisture Content (OMC %)	10 – 12.5
Maximum dry density (MDD g/cc)	1.76 – 1.80
Strength Parameters At OMC & MDD	
C (t/m^2)	1.6 – 3.0
Φ (Degrees)	22 – 28
Strength Parameters At Saturated Condition	
C_s (t/m^2)	0.8-1.8
Φ_s (Degrees)	16 – 20
CBR%	5.3 – 6.2

- Grain size distribution analysis shows that red soils are dominated by sand particles of ranging from 56 – 80% and fines in the range of 20 - 44% out of which silt particles are in the range of 12 – 28% and clay particles are in the range of 8 – 16%.
- It is identified that liquid limit is in the range of 25 - 34%, and Plasticity Index is in the range of 7 - 14.
- The maximum dry densities are in the range of 1.76 g/cc – 1.80 g/cc where as OMC values are in the range of 10.0% - 12.5%.
- High shear strength value in terms of cohesion (c) as 3.0 t/m^2 and angle of shearing resistance (φ) as 28^o. Similarly at saturated condition, Cohesion (c_s) as 1.8t/m^2 and (φ_s) as 20^o.
- High liquid limit and high OMC values are due to presence of clay particles.

3.0 Parameters considered in explaining collapsible behavior:

To know the collapsible behavior of red soil in Vishakhapatnam region the following parameters are considered at their remolded conditions are water content, void ratio, porosity and degree of saturation etc. Ten number of red soils of SC nature were considered and these subjected to remolded conditions and their corresponding dry densities, water content, void ratio, porosity and degree of saturation are computed and are shown below:

Table: 2 Variation of water content with dry density

Υ_d (g/cc)→	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8
Soils↓	Water Content ↓			
SC – I	6.00	6.80	7.20	10.50
SC – II	5.90	6.20	7.60	11.20
SC – III	5.80	6.40	8.00	11.30
SC – IV	5.50	6.20	7.20	11.50
SC – V	5.60	6.30	7.00	11.00
SC – VI	5.20	7.30	8.60	10.00
SC – VII	4.80	6.70	8.60	10.20
SC – VIII	4.80	6.10	7.00	11.50
SC – IX	5.40	6.40	7.50	11.80
SC – X	5.60	7.00	9.50	12.00
Range	4.8-6.0	6.1-7.3	7.0-9.5	10.0-12.0

Table: 3 Variation of void ratio and porosity with dry density

Υ_d (g/cc)→	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8
Soils↓	Void Ratio↓				Porosity↓			
SC – I	0.74	0.70	0.62	0.48	42.50	41.10	39.89	32.40
SC – II	0.74	0.67	0.63	0.48	42.50	40.50	38.70	32.40
SC – III	0.72	0.68	0.63	0.50	43.90	41.20	38.70	33.30
SC – IV	0.76	0.70	0.64	0.49	42.90	40.10	39.00	32.90
SC – V	0.75	0.70	0.65	0.48	43.20	41.90	39.40	32.40
SC – VI	0.79	0.70	0.62	0.49	44.13	41.20	38.30	32.80
SC – VII	0.80	0.67	0.62	0.48	44.40	40.11	38.27	32.43
SC – VIII	0.74	0.65	0.64	0.47	42.50	40.20	39.00	31.90
SC – IX	0.78	0.66	0.67	0.50	43.80	42.90	40.10	33.30
SC – X	0.75	0.67	0.60	0.50	42.80	40.10	37.50	33.30
Range	0.72-0.80	0.65-0.70	0.60-0.67	0.47-0.50	42.50-44.40	40.10-42.90	37.50-39.89	31.90-33.30

Table: 4 Variation of saturation water content and degree of saturation with dry density

Υ_d	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8

(g/cc)→								
Soils↓	**Saturation Water Content↓**				**Degree of Saturation↓**			
SC – I	27.80	26.30	23.50	18.05	21.60	25.90	33.20	58.20
SC – II	27.80	25.60	23.70	18.05	21.20	27.20	32.10	62.07
SC – III	27.06	25.40	23.70	18.80	19.70	26.30	33.80	60.10
SC – IV	28.50	25.90	24.00	18.40	19.32	26.20	30.00	62.70
SC – V	28.20	25.20	24.40	18.10	19.86	26.50	28.70	61.00
SC – VI	29.69	26.32	23.30	18.42	17.50	27.74	36.89	54.28
SC – VII	30.67	25.18	23.30	18.04	15.96	26.60	36.89	56.52
SC – VIII	27.00	25.70	27.00	17.60	17.32	27.56	29.20	65.30
SC – IX	29.20	25.48	25.00	18.70	18.50	26.89	30.00	63.00
SC – X	28.09	25.10	22.50	18.70	19.93	27.90	42.30	64.00
Range	27.80-30.67	25.10-26.32	22.50-27.00	17.60-18.80	15.96-21.60	25.90-27.90	28.70-42.30	54.28-65.30

Table: 5 Variation of Denisov's coefficient with dry density

γ_d (g/cc)→	**1.4-1.5**	**1.5-1.6**	**1.6-1.7**	**1.7-1.8**
Soils↓	**Denisov's coefficient of subsidence↓**			
SC – I	1.01	1.07	1.12	1.56
SC – II	0.97	1.02	1.14	1.50
SC – III	1.07	1.24	1.22	1.54
SC – IV	1.05	1.29	1.25	1.63
SC – V	0.92	1.09	1.06	1.44
SC – VI	0.84	0.95	1.07	1.35
SC – VII	0.84	0.95	1.07	1.35
SC – VIII	0.92	1.12	1.30	1.76
SC – IX	1.09	1.26	1.27	1.70
SC – X	1.17	1.31	1.46	1.76
Range	0.84-1.17	0.95-1.31	1.06-1.46	1.35-1.76

Table: 6 Variation of Gibbs Ratio with dry density

γ_d (g/cc)→	**1.4-1.5**	**1.5-1.6**	**1.6-1.7**	**1.7-1.8**
Soils↓	**Gibbs Collapsible ratio↓**			
SC – I	0.99	0.94	0.89	0.65
SC – II	1.03	0.97	0.88	0.67
SC – III	1.04	0.95	0.82	0.65
SC – IV	1.09	0.98	0.80	0.62
SC – V	1.18	1.05	0.94	0.70
SC – VI	1.15	0.96	0.93	0.74
SC – VII	0.87	0.81	0.89	0.69
SC – VIII	0.91	0.78	0.77	0.56
SC – IX	0.85	0.76	0.78	0.58
SC – X	0.97	0.88	0.68	0.56
Range	1.18-0.85	0.76-1.05	0.68-0.94	0.56-0.69

Table: 7 Variation of Feda with dry density

γ_d (g/cc)→	**1.4-1.5**	**1.5-1.6**	**1.6-1.7**	**1.7-1.8**
Soils↓	**Feda ↓**			
SC – I	0.98	0.81	0.45	- 0.11
SC – II	1.10	0.78	0.59	-0.12
SC – III	0.80	0.45	0.47	-0.02
SC – IV	0.86	0.56	0.46	-0.02
SC – V	1.31	1.01	0.07	-0.14
SC – VI	1.67	1.18	0.75	0.06
SC – VII	1.50	0.89	0.66	0.01

SC – VIII	0.77	0.39	0.39	-0.24
SC – IX	0.76	0.40	0.42	-0.11
SC – X	0.62	0.39	0.18	-0.09
Range	0.62-1.67	0.39-1.18	0.18-0.75	0.06- -0.24

4. DISCUSSIONS:

Based on the test results the degree of collapsible behavior is explained as follows:

Soils compacted at densities in between 1.4g/cc – 1.5g/cc.

- Red soils compacted at very low water contents of 4.8-6.0% have exhibited void ratios as 0.80 – 0.72 and their corresponding porosity was 42.50 - 44.40% and saturation water contents are 27.80 - 30.67%. At these compacted dry densities and water contents these soils attained degree of saturation in the range of 15.96 - 21.60%. At these densities the Denisov's coefficient of subsidence (k) is in the range of 0.84 – 1.17, which is in the range of 0.75 – 1.5 exhibited moderate collapsibility. At these densities Gibb's collapsible ratio (R) is in the range 1.18 - 0.85, which are greater than 1, show high potential for collapsibility. At these densities Feda K_L is in the range 0.62-1.67, which is greater than 0.85, shows collapsibility.

Soils compacted at densities in between 1.5g/cc – 1.6 g/cc.

- Red soils compacted at very low water contents 5.10-7.30%, have exhibited void ratios as 0.70-0.65 and their corresponding porosity was 40.10 – 42.90% and saturation water contents are 25.10-26.32. At these compacted dry densities and water contents these soils attained degree of saturation in the range of 25.90–27.90%. At these densities the Denisov's coefficient of subsidence (k) is in the range of 0.95 – 1.31, which is in the range of 0.75 – 1.5 exhibited moderate collapse. At these densities Gibb's collapsible ratio (R) is in the range 0.76 –1.05, which are greater than 1, show high potential for collapsibility. At these densities Fedas K_L is in the range 0.39-1.18, which are greater than 0.85, shows collapsible.

Soils compacted at densities in between 1.6g/cc – 1.7 g/cc.

- Red soils compacted at very low water contents 7.0–9.5%, exhibited void ratio as 0.60 – 0.67 and their corresponding porosity was 37.50 – 39.89% and saturation water contents are 22.50-27.00. At these compacted dry densities and water content these soils attained degree of saturation in the range of 28.70-42.30%. At these densities the Denisov's coefficient of subsidence (k) is in the range of 1.06-1.46, which is in the range of 0.75 – 1.5 exhibited moderate collapse. At these densities Gibb's collapsible ratio (R) is in the range 0.68-0.94, which are less than 1, show free from collapsibility. At these densities Fedas K_L is in the range 0.18-0.75, which is less than 0.85, shows non-collapsible.

Soils compacted at densities in between 1.7g/cc – 1.8 g/cc.

- Red soils compacted at very low water contents 10.0 – 12.0%, exhibited void ratio 0.47 – 0.50 and their corresponding porosity was 31.90-33.30% and saturation water contents are 17.60-18.80%. At these compacted dry densities and water content these soils attained degree of saturation in the range of 54.28-65.30%. At these densities the Denisov's coefficient of subsidence (k) is in the range of 1.35-1.76, which is in the range of 1.5 – 2.0 exhibited moderate collapse. At these densities Gibb's collapsible ratio (R) is in the range 0.56-0.69, which are less than 1, show free from collapsibility. At these densities Feda (K_L) is in the range 0.06 - -0.24, which are less than 0.85, shows non-collapsible.

From the analysis it is identified that soils at very low water content (4.8- 6.0%) posses low dry densities (1.4-1.5g/cc), which are in dry state with honey-comb structure having high air voids and porosity. At this state the soils are deficient in moisture to become saturate, upon saturation these air voids are replaced with water and loss of clay particles and inherent oxides due to softening of the soils etc., this result in decrease of volume soils leads to collapsibility.

As the water content is increasing dry densities are also increasing which helps in decreasing void ratio and increasing degree of saturation. Therefore particle to particle contact is increasing and arrangement of particles in to closed packing, than honey combing takes place. This phenomenon decreases the degree of collapsibility. Further increase of water content, make the particles in dense packing with high dry densities and high degree of saturation leads to very less volume reduction on saturation results the soils are free from collapsibility. This phenomenon accepts with the models of Denisov's (1951), Clevenger (1956), Gibbs (1961), and Handy (1973).

5. CONCLUSION:

By observing results from the consistency, grain size distribution and compaction test and index parameters at various compacted conditions the following conclusions have drawn.

- Collapsibility occurs at low percentages of clay contents with, low dry densities (less than 1.6 g/cc), low moisture contents (4.8 – 6.0%) and low liquid limits (less than 30%) and porosity greater than 40%, high void ratios etc.
- Red soils at dry densities nearing to maximum dry densities(1.7-1.8 g/cc) and their corresponding degree of saturation, void ratios are free from collapsibility

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