Role of Engineering Properties in Prediciting Collapisble Behaviour of Red Soils

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Abstract

Moisture-sensitive soils prone to collapsing and losing their strength on wetting. Collapse characteristics contribute various problems to infrastructures that are constructed on red soils. The chief problems are decreasing volume causes differential settlements. Finally these soils induce stresses on supporting structures. In the present study an attempt is made with 10 red soils for various geotechnical characteristics to relate the collapsibility of these soils by considering parameters like water content, dry density, saturation moisture content, void ratio and porosity etc., the degree of collapsibility if these soils are explained with existing models.

Keywords - *Moisture sensitive, Collapse Characteristics, differential settlements.*

I. INTRODUCTION

Collapsible soils undergo sudden change in volume and collapse when the moisture contents increases to saturation. Almost all naturally occurring collapsible soil deposits are wind deposits. The amount of collapse is usually a function of different parameters, including soil particles, degree of saturation, initial void ratio. Visakhapatnam Region has been with full of Red soils. Geotechnical Engineers in this region has been facing problem of subsidence due to decrease of volume of soil on saturation with or without loading. In this aspect understanding the collapsible behaviour of Red soils is necessary. In The present investigation 10 no of red soils have been tested for geotechnical characterization at various compacted conditions and these verified with respect to the existing models like Denisov's.(1951); Feda. (1966); Gibbs and Holland. (1960) etc.

A. Exciting methods of Estimation of Collapsible Potential

1.Denisov's (1951):

Uses the coefficient of subsidence for identifying collapsible behaviour.

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 remoulded 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;

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. 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);

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.

II. MATERIALS, TESTS & RESULTS

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.

Table 1: Geotechnical Properties Of Red Soils (Sm) Of Visakhapatnam Region

Property	**Values**
Gradation Properties	
Gravel (%)	0
Sand (%)	74 – 85
Fines (%)	15 – 26
Silt (%)	14 – 21
Clay (%)	0 – 6
Specific Gravity (G)	2.65 – 2.66
Index Properties	
Liquid Limit (%) (W_L)	20 – 23
Plastic Limit (%) (W_P)	17 – 19
Plasticity Index (I_p)	3 – 4
IS Classification	SM
Compaction Characteristics	
Optimum Moisture Content (OMC %)	8.8 – 9.5
Maximum dry density (MDD g/cc)	1.68 – 1.75
Strength Parameters At OMC & MDD	
C (t/m^2)	1.0 -1.4
Φ (Degrees)	28-30
Strength Parameters At Saturated Condition	
C_s (t/m^2)	0.4 – 0.8
$Φ_s$ (Degrees)	20-24
CBR%	4.2 – 5.0

- Grain size distribution analysis shows that red soils are dominated by sand particles (4.75 mm – 0.075mm) of ranging from 74 – 85% and fines (< 0.075 mm) in the range of 15 – 26% out of which silt particles (0.075mm – 0.002mm) are in the range of 14 – 21% and clay particles (< 0.002 mm) are in the range of 0 – 6%.
- It is identified that liquid limit is in the range of 20 - 23%, and Plasticity Index is in the range of 3-4.
- The maximum dry densities are in the range of 1.68 g/cc – 1.75 g/cc where as OMC values are in the range of 8.8% - 9.5%.
- High shear strength value in terms cohesion (c) as 1.4 t/m^2 and angle of shearing resistance (φ) as 30°. Similarly at saturated condition, Cohesion (c_s) as 0.8t/m^2 and ($φ_s$) as 24°.

A. Parameters considered in explaining collapsible behaviour

To know the collapsible behaviour of red soil in Vishakhapatnam region the following parameters are considered at their remoulded conditions are water content, void ratio, porosity and degree of saturation etc. Ten number of red soils of SM 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 ↓**			
SM – I	3.6	5.0	8.2	9.2
SM – II	3.2	5.8	8.5	9.0
SM – III	3.2	5.5	8.6	9.4
SM – IV	3.0	5.3	7.6	9.0
SM – V	3.2	7.0	8.8	9.1
SM – VI	3.4	6.5	8.0	9.3
SM – VII	3.8	6.8	8.3	9.2
SM – VIII	3.0	6.5	8.0	9.0
SM – IX	4.0	6.8	8.5	9.5
SM – X	2.9	6.5	8.4	9.1
Range	2.9 - 4.0	5.0 - 7.0	7.6 – 8.8	9.0 – 9.5

Table: 3Variation 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↓			
SM – I	0.76	0.72	0.63	0.52	43.20	41.90	38.70	34.20
SM – II	0.78	0.66	0.56	0.52	43.80	40.00	35.90	34.20
SM – III	0.77	0.70	0.60	0.50	43.50	41.20	37.50	33.30
SM – IV	0.77	0.72	0.56	0.51	43.50	42.00	35.90	34.20
SM – V	0.83	0.69	0.58	0.51	45.40	40.80	36.70	32.10
SM – VI	0.79	0.69	0.59	0.54	44.10	40.80	37.10	35.10
SM – VII	0.79	0.67	0.60	0.53	44.10	40.10	37.50	34.60
SM – VIII	0.84	0.70	0.58	0.55	45.65	41.17	36.70	35.48
SM – IX	0.81	0.70	0.56	0.51	44.80	41.12	35.90	33.80
SM – X	0.79	0.69	0.58	0.54	44.40	40.80	36.00	35.00
Range	0.84 – 0.76	0.72 – 0.66	0.63-0.56	0.58 – 0.50	43.2 – 45.7%	40 – 42%	35.9 – 38.7%	33.3-36.7%

Table: 4Variation of saturation water content and degree of saturation 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↓	Saturation Water Content↓				Degree of Saturation↓			
SM – I	28.70	27.20	23.80	19.60	12.60	18.40	34.50	46.90
SM – II	29.40	24.90	21.10	19.60	10.90	23.30	40.20	45.90
SM – III	29.10	20.75	22.64	18.90	11.01	20.82	38.00	49.82
SM – IV	29.06	27.20	21.10	19.60	10.33	19.50	36.00	45.90
SM – V	31.30	26.00	21.90	19.20	10.22	26.90	40.20	42.80
SM – VI	29.80	26.00	22.20	20.40	11.40	25.00	35.90	45.60
SM – VII	29.80	25.30	22.60	20.00	12.80	26.90	36.70	46.00
SM – VIII	31.69	26.40	21.80	20.70	9.46	24.60	36.55	43.36
SM – IX	30.50	26.30	21.10	19.20	13.14	25.90	40.40	49.60
SM – X	29.80	26.00	21.00	20.00	9.70	24.90	38.30	44.65
Range	28.7-31.7	20.75-27.2	21.0-23.8	18.9-21.9	9.5 – 13.2	18.4 – 26.9	34.50 – 40.4	40.4 - 49.8

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

Υ_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↓			
SM – I	0.77	0.81	0.93	1.12
SM – II	0.72	0.85	1.00	1.08
SM – III	0.79	0.87	1.02	1.22
SM – IV	0.76	0.81	1.04	1.12
SM – V	0.67	0.81	0.97	1.02
SM – VI	0.74	0.85	0.99	1.08
SM – VII	0.76	0.90	1.0	1.13
SM – VIII	0.68	0.81	0.98	1.04
SM – IX	0.78	0.90	1.12	1.24
SM – X	0.73	0.84	1.01	1.07
Range	0.67 – 0.79	0.81 – 0.90	0.93 – 1.20	0.97 – 1.24

Table: 6 Variation of Gibbs Ratio with dry density

Υ_d (g/cc)→	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8
Soils↓	Gibbs Collapsible ratio↓			
SM – I	1.31	1.24	1.10	0.89
SM – II	1.40	1.19	1.00	0.93
SM – III	1.27	0.90	0.94	0.82
SM – IV	1.32	1.24	0.96	0.89
SM – V	1.49	1.24	1.04	0.92
SM – VI	1.35	1.18	1.01	0.93

SM – VII	1.33	1.13	1.01	0.89
SM – VIII	1.47	1.23	1.01	0.96
SM – IX	1.30	1.12	0.9	0.82
SM – X	1.35	1.18	0.95	0.90
Range	1.27- 1.49	0.9 – 1.24,	0.9 – 1.1	0.82-0.96

Table: 7Variation of Feda with dry density

Υ_d (g/cc)→	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8
Soils↓	**Feda ↓**			
SM – I	2.64	2.29	1.44	0.40
SM – II	3.79	2.30	1.05	0.54
SM – III	2.52	1.85	0.91	-0.03
SM – IV	2.76	2.30	0.78	0.40
SM – V	3.58	2.26	1.22	0.52
SM – VI	3.61	2.33	1.10	0.46
SM – VII	2.92	1.82	1.15	0.50
SM – VIII	3.55	2.23	1.10	0.81
SM – IX	2.74	1.69	0.39	-0.09
SM – X	3.25	2.17	0.98	0.53
Range	2.64-3.79	1.69 – 2.33	0.39-1.44	0.81- -0.09

III. DISCUSSIONS

A. Based on the test results the degree of collapsible behaviour is explained as follows

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

Red soils compacted at very low water contents of 2.9-4.0% have exhibited void ratios as 0.84 – 0.76 and their corresponding porosity was 43.2 – 45.7% and saturation water contents are 28.7-31.8%. At these compacted dry densities and water contents these soils attained degree of saturation in the range of 9.5 – 13.2%. At these densities the Denisov's coefficient of subsidence (k) is in the range of 0.67 – 0.79, which is in the range of 0.5 – 0.75 exhibited high risk of collapsibility. At these densities Gibb's collapsible ratio (R) is in the range 1.27- 1.49, which are greater than 1,show high potential for collapsibility. At these densities Fedas K_L is in the range 2.64-3.79, which are greater than 0.85, shows collapsibility.

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

Red soils compacted at very low water contents 5.0 - 7.0%, have exhibited void ratios as 0.72 – 0.66 and their corresponding porosity was 40 – 42% and saturation water contents are 20.75-27.2. At these compacted dry densities and water contents these soils attained degree of saturation in the range of 18.4 – 26.9%. At these densities the Denisov's coefficient of subsidence (k) is in the range of 0.81 – 0.90, 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 0.9 –1.24, which are greater than 1, show high potential for collapsibility. At these densities Fedas K_L is in the range 1.69 – 2.33, which are greater than 0.85, shows collapsible.

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

Red soils compacted at very low water contents 7.6–8.8 %, exhibited void ratio as 0.63 – 0.56 and their corresponding porosity was 35.9 – 38.7% and saturation water contents are 21.0-23.8. At these compacted dry densities and water content these soils attained degree of saturation in the range of 34.50 – 40.4%. At these densities the Denisov's coefficient of subsidence (k) is in the range of 0.93 – 1.2, 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 0.9 – 1.1, which are less than 1, show free from collapsibility. At these densities Fedas K_L is in the range 0.39-1.44, which is greater than 0.85, shows collapsible.

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

Red soils compacted at very low water contents 9.0 - 9.5 %, exhibited void ratio 0.58 – 0.50 and their corresponding porosity was 33.3-36.7% and saturation water contents are 18.9-21.9. At these compacted dry densities and water content these soils attained degree of saturation in the range of 40.4 - 49.8%. At these densities the Denisov's coefficient of subsidence (k) is in the range of 0.97 – 1.24, 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 0.82-0.96, which are less than 1, show free from collapsibility. At these densities Feda (K_L) is in the range 0.81- -0.09, which are less than 0.85, shows non-collapsible.

From the analysis it is identified that soils at very low water content (2.9-4.0%) 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., results 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 and particle to particle contact is increasing and arrangement of particles in to closed packing than honey combing. 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).

IV. 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 (less than 6), low dry densities (less than 1.6 g/cc), low moisture contents (2.9-4%) and low liquid limits (less than 25%) 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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