Effect of Different Densities and Saturation on Unconfined Compressive Strength of Expansive & Yellow Plastic Clay

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Abstract. It is well-known that the effects of saturation and maximum dry density can be enormous on the unconfined compressive strength of the soil. This article asserts the existence of a huge change in the behaviour of the unconfined compressive strength of soil at the combined effect of different densities and saturation conditions. This experiment was done on expansive soil and yellow plastic clay taken from different cities of south Gujarat region in India. The findings show a unique behaviour of the strength of soil at the standard Proctor test's maximum dry density with the combination of various saturation conditions. A unique upward trend was noticed at the standard Proctor test density at different saturation conditions. Also, different saturation conditions were derived from the experiment.

Keywords**:** density, saturation, unconfined compressive strength, expansive soil, plastic clay.

1. Introduction

During the construction of a fill or embankment, the degree of saturation of the compacted soils is usually, in an unsaturated condition, controlled at around 60% to 70% for maximum dry density (Jonggil et al. 2010). Due to natural factors, the strength of soil decreases quickly, which will often cause the shear failure of soil during the rainy season (Wen et al. 2014). Soil stabilization through mechanical and chemical processes is commonly used to enhance soil properties such as increasing the shear strength of the soil (Yuskel et al. 2017). This work is mainly focused on the study of the unconfined compressive strength of saturated soil which mainly depends on saturation percentage and dry density (Hongsheng et al. 2001). In past decades, lots of research has been done by introducing various materials whether it maybe lime, fly ash or certain add mixtures. But this present study provides the relation between densities and various saturation conditions, to identify the particular saturation percentage at which soil gives better strength. The tests were made by remoulding the sample at each considered densities by the help of standard and modified Proctor test at 80, 85, 90, 95 & 100% of saturation (Shah et al. 2018). The physical properties, standard and modified Proctor tests have been done twice to get accurate results and the average value has taken into consideration. The unconfined compressive strength test has been done by remoulding the sample and from every mould, three samples were extracted an average value has been considered. From specific gravity and dry density, saturation is derived and we consider 80 to 100% of saturation with the interval of 5%. Repetitions have been done if necessary. The purpose of this study is to discover the effect of saturation on unconfined compressive strength at every possible condition.

2. Method

2.1 Material

In this experiment, four types of soils are collected from two different cities of South Gujarat region which are (1) expansive soil (ES) and (2) yellow plastic clay (YS) from Silvasa and Bharuch cities. Table 1 presents the physical properties and both Proctor test results, which mentions grain size analysis, atterberg limits, IS classification, free swell index, specific gravity, standard Proctor test and modified Proctor test results. All of the tests are performed twice.

Table 1. Physical Properties

Soil Property	Silvasa ES	Bharuch ES	Silvasa YS	Bharuch YS
Gravel %	1	0	10	22
Coarse Sand %	1	1	10	9
Medium Sand %	0	0	8	6
Fine Sand %	5	2	5	26
Silt + Clay (%)	91	97	66	37
Liquid Limit%	52	60	53	41
Plastic Limit %	22	25	24	20
Plasticity Index %	30	35	29	21
IS Classification	CH	CH	CH	SC
Specific Gravity gm/cm^3	2.669	2.464	2.672	2.835
Free Swell Index %	54	55	24	36
S.OMC[a] (Standard) %	22.5	20.8	21.87	20.01
S.MDD[b] (Standard) gm/cm^3	1.602	1.651	1.633	1.652
M.OMC[c] (Modified) %	18.7	18.3	19.24	16.25
M.MDD[d] (Modified) gm/cm^3	1.851	1.752	1.771	1.805

[a.] S.OMC = Standard proctor test optimum moisture content
[b.] S.MDD = Standard proctor test maximum dry density
[c.] M.OMC = Modified proctor test optimum moisture content
[d.] M.MDD = Modified proctor test maximum dry density

2.2 Instruments

The instruments used are a mould with a diameter of 100 mm, height 125 mm. Three sample tubes with a diameter of 28 mm and height 130 mm. Sampler with a diameter of 28 mm and height 74 mm. A plunger with 20 mm thickness and 98 mm the diameter. Hydraulic sample extractor is needed to compress and also extract the sample from the mould (Shah et al. 2018). Three-layer measurement tools were also used. The instruments used are different than the universal remoulding tool. This mould is used to extract three samples from the same mould to get more uniformity in the specimens.

2.3 Experimental Calculations

All the tests are done regarding the Indian Standards. Now for calculation of saturation moisture content, specific gravity is an important factor thus we determined specific gravity until we get the accuracy to 0.03gm/cm^3. The equations used in determining the saturation and bulk density are mentioned below as equation 1 & 2,

$$M/C = \frac{S\gamma \times \left(\left(\frac{G}{\rho d}\right) - 1\right)}{G} \tag{1}$$

$$\rho = \rho d \times \left(1 + \frac{S\gamma}{100}\right) \tag{2}$$

Where, M/C = moisture content, S_γ = saturation percentage, G = specific gravity, ρ_d=dry density, ρ=bulk density.

2.4 Sample Preparation

Now to determine compaction test, we add 10% of moisture in the soil and put it into a desiccator and put the desiccator partly submerged in 27°C water to let the soil distribute moisture evenly. By doing this we encountered more accurate results of compaction test and repetitions also gave the same accurate results. From this experiment, we followed these steps for remoulding the sample also. The remoulding is done in three equal layers and compressed it in the mould hydraulically. After the remoulding, the sample is extracted in three tubes with the help of sample extractor. From the tubes, extracted sample used to prepare unconfined compressive strength test specimens. The size of the specimen is 38 mm in the diameter and 76 mm in height.

3. Results and discussion

3.1 UCS of Expansive Soils

The considered densities in Silvasa expansive soil are 1.60, 1.65, 1.70, 1.75, 1.80 and 1.85 gm/cm^3 out of which 1.60 gm/cm^3 is standard Proctor test density and 1.85 gm/cm^3 is modified Proctor test density. Now, for each density, the saturation moisture content is introduced from 80 to 100% with an interval of 5%. The test results are mentioned in table 2 below and all the units of unconfined compressive strength test results are in kg/cm^2. UCS describes unconfined compressive strength and is denoted as q_u.

Table 2. Silvasa Expansive Soil UCS Results

	q_u Avg. kg/cm^2					
Saturation	q_u @ 1.6	q_u @ 1.6	q_u @ 1.6	q_u @ 1.6	q_u @ 1.6	q_u @ 1.6
80%	2.76	2.6	4.18	3.69	4.82	6.89
85%	3.08	2.84	3.86	3.9	4.73	5.44
90%	2.63	3.1	4.53	5.81	5.28	10.02
95%	3.53	1.95	3.03	2.44	4.5	5.02
100%	3.71	1.81	2.16	2.3	3.99	4.36

The considered densities for Bharuch expansive soil are 1.55, 1.60, 1.65, 1.70 and 1.75 gm/cm^3 out of which 1.65 gm/cm^3 is standard Proctor test and 1.75 gm/cm^3 is modified Proctor test. The test results are mentioned in table 3.

Table 3. Bharuch Expansive Soil UCS Results

	q_u Avg. kg/cm^2				
Saturation	q_u @ 1.55	q_u @ 1.60	q_u @ 1.65	q_u @ 1.70	q_u @ 1.75
80%	7.34	8.32	9.81	9.14	12.25
85%	7.55	8.21	7.61	11.18	16.89
90%	8.48	10.64	5.88	13.03	21.51
95%	4.64	9.49	6.87	12.39	19.08
100%	3.68	6.9	7.93	11.36	12.58

Now before the standard Proctor test density, both the soils show almost the same behaviour and gives better strength at 90% of saturation. At standard Proctor test density, the upward trend is noticed from 90 to 100% saturation which is remarkable. And after standard Proctor to modified Proctor test density, soil gives better strength at 90% of saturation condition for both the soils.

3.2 UCS of Yellow Plastic Clays

For Silvasa yellow plastic clay, densities are 1.58, 1.63, 1.68, 1.73 & 1.78 gm/cm^3 from which 1.63 gm/cm^3 is standard Proctor test density and 1.78 gm/cm^3 is modified Proctor test density. All the densities are remoulded at 80, 85, 90, 95 & 100% saturation. Results mentioned in Table 4.

Table 4. Silvasa Yellow plastic clay UCS Results

	q_u Avg. kg/cm^2				
Saturation	q_u @ 1.58	q_u @ 1.63	q_u @ 1.68	q_u @ 1.73	q_u @ 1.78
80%	4.41	5.18	4.73	5.63	5.99
85%	4.38	7.68	4.81	7.52	5.2
90%	5.13	5.63	5.19	7.88	6.55
95%	4.26	6.58	7.1	9.72	8.76
100%	3.53	8.22	3.25	5	5.76

And for Bharuch yellow plastic clay, 1.6, 1.65, 1.70, 1.75 and 1.80 gm/cm^3 are the desired densities and 1.65 gm/cm^3 is standard Proctor test density and 1.80 is gm/cm^3 modified Proctor test density. All these densities are remoulded at 5% interval of saturation from 80 to 100%. Table 5 elaborates the test results.

Table 5. Bharuch Yellow plastic clay UCS Results

	q_u Avg. kg/cm^2				
Saturation	q_u @ 1.6	q_u @ 1.65	q_u @ 1.7	q_u @ 1.75	q_u @ 1.80
80%	2.82	3.22	5.04	6.16	8.52
85%	2.7	2.87	3.92	5.25	5.34
90%	2.08	3.06	4.47	5.29	4.91
95%	1.59	3.56	4.87	5.61	5.51
100%	1.31	3.78	3.09	3.49	4.75

Figure 1 clearly shows all the results of the standard Proctor test density at different saturation conditions.

In the beginning, before standard Proctor test density, soil shows almost the same strength behaviour and gives better strength at 90% of saturation. At standard Proctor test density, it goes rising from 90 to 100% saturation which is worthy of attention. And after standard Proctor test density till modified Proctor test density, soil shows the best strength at 95% of saturation.

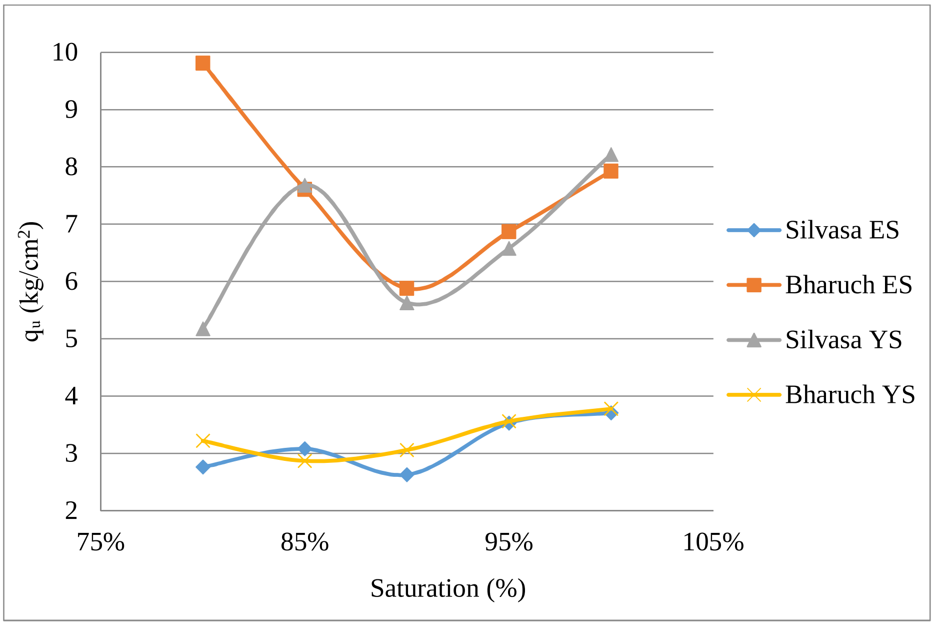

Fig. 1. UCS v/s Saturation

4. Conclusions

- In the early stage, before standard Proctor test density, soil behaves almost the same in both types.
- For expansive soil, it gives more strength at 90% of saturation before standard Proctor test density. At standard Proctor test density, it goes upward from 90 to 100% saturation. And after standard till modified Proctor test density, it also gives better strength at 90% of saturation.
- For yellow plastic clay, the peak saturation is 90% before standard Proctor test density. At standard Proctor test density, it goes upward from 90 to 100% saturation. And till modified Proctor test density it gives maximum strength at 95% of saturation.
- Hence, from this experiment, we can evaluate that, the expansive soil is saturated at 90% of saturation after and below standard Proctor test density and for yellow plastic clay, 90% is saturation condition below standard Proctor and 5% above standard Proctor test density. And for both the soils, 100% at standard Proctor test density is the saturated condition.

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