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Geotechnical Properties of Expansive Soil at Varying Salt Content

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ABSTRACT

Black Cotton soils have the tendency to increase in volume when water is available and decrease in volume when water is available and decrease in volume when water is removed. The problem in black cotton Soils is that deformations are significantly greater.These deformations cannot be predicted because Movement of soils is usually in an uneven manner. At this stage the soil is to be needed stabilized. The chemical stabilization revealed that strong Electrolytes like sodium chloride (NaCl) . Sea Salt, also known as common salt, table salt, or halite, is a chemical compound with the formula NaCl.).Sea Salt is present in ample of quantity in India. However less work has been carried out on sea salt which is also available in large amount with minimum cost or no cost. So there is need to study the effect of sea salt on engineering properties of expansive soil like black cotton soil can be used. Laboratory tests will be conducted on these soil mixes to assess various properties, including Free Swell Index, Atterberg Limits, Sieve Analysis, Shrinkage Limit, Specific Gravity, Compaction, Unconfined Compression, California Bearing Ratio, Swelling Pressure, and X-Ray Diffraction.

Key words: Black cotton soil, Sodium chloride (NaCl), Geotechnical properties

INTRODUCTION

Various challenges which are faced during after the construction of structure in Black cotton soil due to its poor bearing capacity. In this research study black cotton soil is collected from Karjan, Vadodara, Gujarat. In the research, the Free Swell Index was evaluated at various salt contents of 2%, 4%, 6%, 8%, and 10%. The results showed that the greatest reduction in the index occurred at 8% salt content, leading to the selection of 8% for further tests.

Prakhar and Rajesh (2015) investigated the impact of common salt (NaCl) on the engineering properties of black cotton soil. Their study involved mixing the soil with NaCl at concentrations of 0%, 2%, 4%, 6%, and 8% (by dry weight). The results indicated that increasing NaCl concentration led to a decrease in the free swell index and optimum moisture content, while the maximum dry density, California bearing ratio, and unconfined compressive strength increased. Ramadas et al. (2012) examined the effects of various percentages of calcium chloride, finding that it reduced plasticity and enhanced strength, which led to the formation of shrinkage cracks. G.R. Qtoko (2014) studied the effects of saltwater on the physical properties, compaction characteristics, and unconfined compressive strength of clay, clayey sand, and base course materials. Ata (2014) reported that for clays with more than 72% montmorillonite and a liquid limit exceeding 140%, the use of saltwater in mixing significantly reduced the liquid limit and swelling potential. Additionally, H. Magdi M. E. Durotoye et al. (2016) discovered that adding 1.5% sodium chloride to soil resulted in significant reductions: 60.42% in liquid limit, 42.86% in plastic limit, 71.26% in plasticity index, 83.43% in free swell index, and 28.57% in optimum moisture content.

percentage higher than 72% and having a liquid limit higher than 140% when mixed with distilled water show that the liquid limit and the swelling potential are significantly reduced if saltwater is used in mixing. h.MagdiM. E. Zumrawi et al., (2016) studied the effect of some chloride salts on consistency and swelling characteristics of expansive Soil. The results inferred were the addition of chloride salt to the expansive clay decreased the liquid limit and the plasticity index of the treated soil. Durotoye et al., (2016). Found that addition of 1.5% sodium chloride to the soil, maximum reduction percentage of 60.42% on liquid limit, 42.86% on plastic limit, 71.26% on plasticity index, 83.43% on free swell index and 28.57% on optimum moisture content. Addition of 1.5 % sodium chloride to the soil.

Experimental investigation

Geotechnical properties of Expansive soil with and without soil content

The geotechnical properties of expansive soil have found out by standard procedures given in the IS codes (IS 2720) and summarized in below **table.1**

Table 1 Index Properties of Black Cotton soil with (NaCl)

Sr. no	Index and Engineering properties	Normal Karjan soil	Soil with (NaCl)	% INCREASE	% DECREASE
1	Free Swell index %	80	52.27	-	34.6
2	Atterberge's limit				
	Liquid limit test(L.L) %	61.90	33.54	-	45.9
	Plastic Limit (P.L) %	22.80	16.72	-	26.5
	Plasticity Index (PI) %	39.10	16.82	-	56.9
	Shrinkage limit (S.L) %	15.40	10.50	-	31.2
3	Grain size Analysis				
	Clay %	48	35	-	27.1
	Silt %	36.94	44.41	20.2	-
4	Specific gravity (G.S)	2.61	2.78	6.5	-
5	Standard Proctor test				
	OMC (%)	19	14	-	26.3
	MDD (kg/m^3)	1580	1930	22.1	-
6	Unconfined Compressive test (UCS) (kPa)	119.64	183.77	53.6	-
7	California Bearing ratio (CBR) (%)	1.86	2.33	25.4	-
8	Consolidation test (Cc)	0.33	0.35	6.1	-
9	Swell pressure test (kPa)	92.182	64.72	-	29.8

When sodium chloride (NaCl) was added, various soil properties experienced significant changes. The Free Swell Index (F.S.I) decreased by 34.6%, indicating reduced swelling potential. The Liquid Limit (L.L) dropped by 45.9%, while the Plastic Limit (P.L) saw a reduction of 26.5%, both of which suggest a decrease in soil plasticity. Consequently, the Plasticity Index (PI) fell by 56.9%, reflecting a more substantial reduction in the soil's capacity to deform. Additionally, the Shrinkage Limit (S.L) was reduced by 31.2%, which indicates a decrease in the soil's tendency to shrink upon drying. The clay percentage decreased by 27.1%, and the silt percentage saw a decrease of 20.2%, both contributing to changes in soil texture. The specific gravity (Gs) of the soil increased by 6.5%, while the Optimum Moisture Content (OMC) decreased by 26.3%, suggesting a lower moisture requirement for soil compaction. The Maximum Dry Density (MDD) increased by 22.2%, indicating a denser soil structure. In terms of strength, the Unconfined Compressive Strength (UCS) increased by 53.8%, and the California Bearing Ratio (CBR) improved by 25.4%, reflecting enhanced soil stability. The Consolidation test (Cc) value increased by 6.1%, showing a slight rise in compressibility, whereas the swell pressure decreased by 29.8%, further indicating reduced swelling behavior.

EFFECT OF SALT ON PARTICLE SIZE DISTRIBUTION

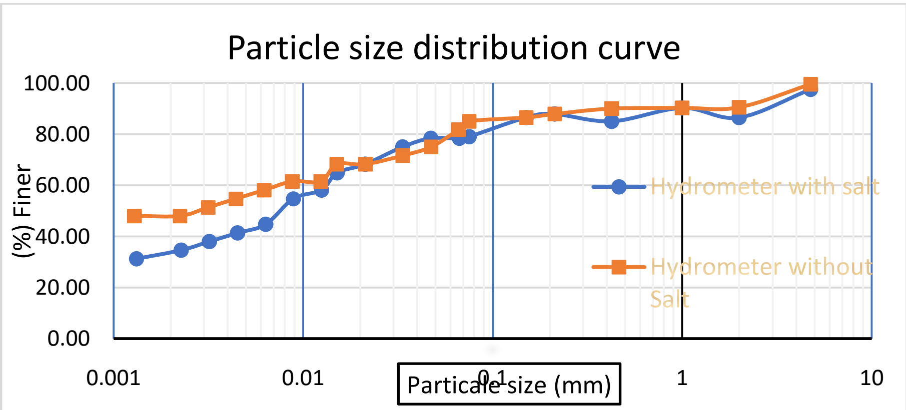

Figure 1 Particle Size Distribution Curve

In accordance with IS: 2720 (Part-4) – 1985, the test results showed that the clay percentage decreased by 27.1% and the silt percentage decreased by 20.2% when an 8% NaCl solution was used.

Table.1.2.Clay and Silt Particle Result with and without NaCl

Clay and Silt particle in Black cotton soil and NaCl		
Parameter	**Natural state**	**Treated state**
Clay (%)	48	35
Silt (%)	36.94	44.41

STANDARD PROCTOR TEST

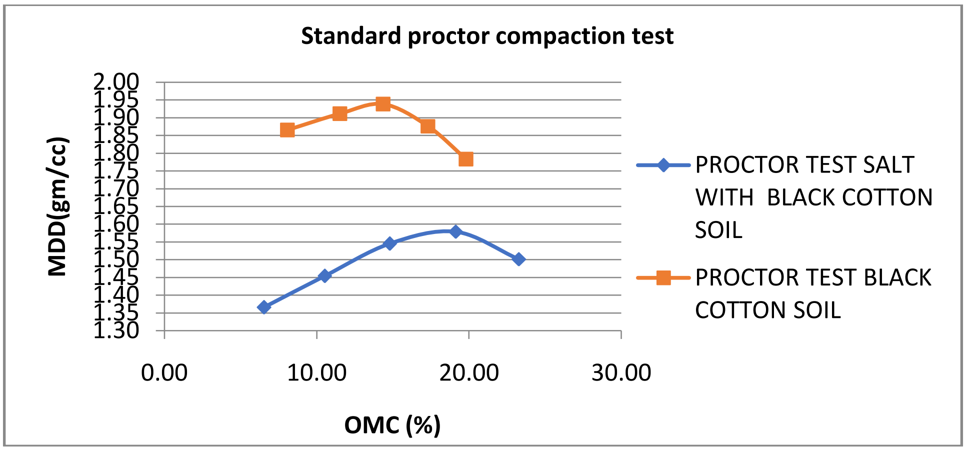

Figure.2. Standard proctor Graph with and without NaCl

The Standard Proctor Test, conducted according to IS: 2720 (Part-8) – 1983, the Result showed that the **(**OMC) decreased by 26.3%,and (MDD) increased by 22.2%.

Table.1.3. Compaction test result with and without NaCl

Compaction test on Black cotton soil and NaCl		
Parameter	**Natural state**	**Treated state**
Optimum moisture content (%)	19.2	14
Maximum dry density (gm/cc)	1.58	1.93

UNCONFINED COMPRESSIVE STRENGTH TEST

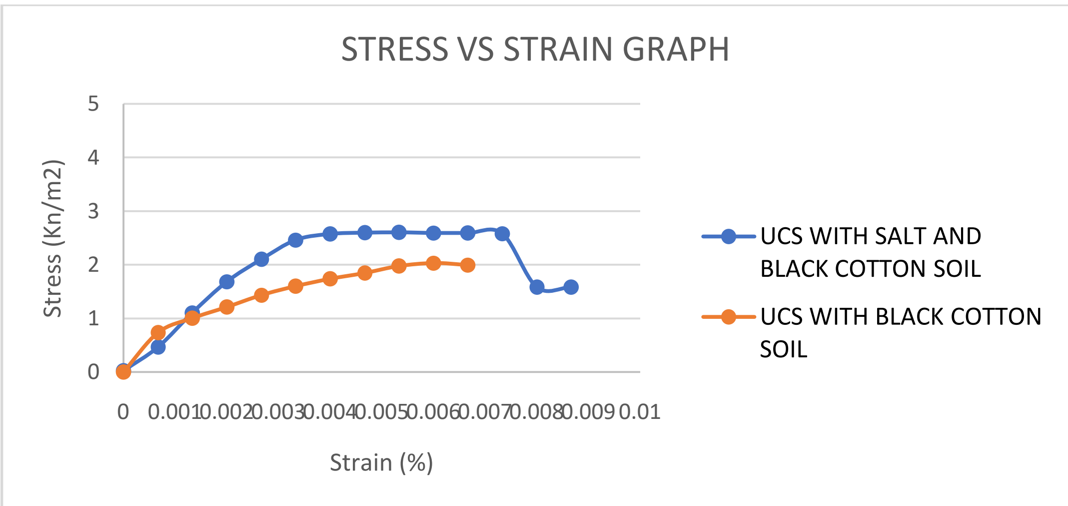

Figure.3. Stress Strain Graph with and without NaCl

The test is performed as per IS: 2720 (Part-10)-1973, the Unconfined Compressive Strength (UCS) increased by 53.8%, when an 8% NaCl solution was used.

Table.1.4.UCS test result with and without NaCl

UCS test on Black cotton soil and NaCl		
Parameter	**Natural state**	**Treated state**
UCS average value (Kpa)	120.03	183.85

CALIFORNIA BEARING RATIO

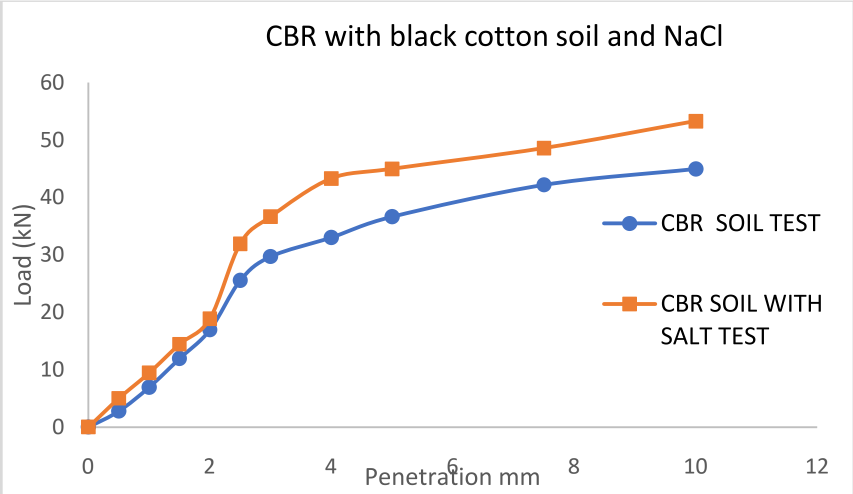

Figure.4.CBR Graph with and without NaCl

The test is conducted in accordance with IS: 2720 (Part-16)-1979, the California Bearing Ratio (CBR) improved by 25.4%, when an 8% NaCl solution was used.

Table.1.5.CBR test result with and without NaCl

CBR test on Black cotton soil and NaCl		
Parameter	**Natural state**	**Treated state**
CBR at 2.5 mm penetration in (%)	1.86	2.33
CBR at 5 mm penetration in (%)	1.78	2.18

Consolidation Test

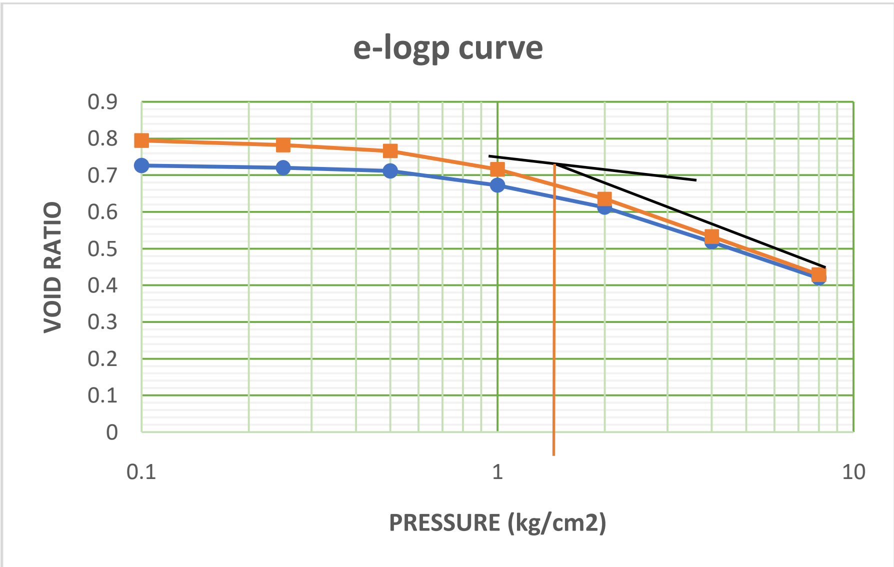

Figure.5.elog p Curve with and without NaCl

This test is performed according to IS: 2720 (Part-15)-1965, The Consolidation test (Cc) value increased by 6.1%, when an 8% NaCl solution was used.

Table.1.6. Consolidation test result with and without Nacl

Consolidation Test on Black cotton soil and NaCl		
Parameter	**Natural state**	**Treated state**
Preconsolidation pressure (Pc),Kpa	156.906	127.486
Compression index (Cc)	0.33	0.35
Coefficient of Compressibility (av)	0.06	0.08
Coefficient of volume change (mv)	0.035	0.047

SWELL PRESSURE TEST

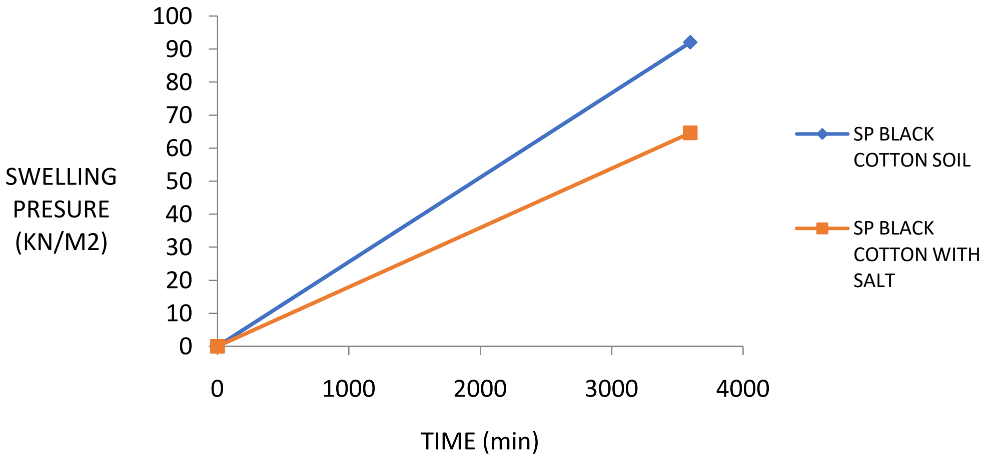

Figure.6. Swell pressure Graph with and without NaCl

The test was conducted following IS 2720 (Part-41) 1977, the swell pressure decreased by 29.8%, when an 8% NaCl solution was used

Table.1.7.Swell pressure test result with and without NaCl

Swell Pressure on Black cotton soil		
Parameter	**Natural state**	**Treated state**
Swell Pressure	92.182	64.72

X-RAY DIFFRECTION TEST

In X-ray diffraction test montmorillonite's peak typically decrease with the addition of 8% salt. This reduction occurs because salt ions disrupt the interlayer cation of montmorillonite, altering its structure and resulting in reduced diffraction peak intensity.

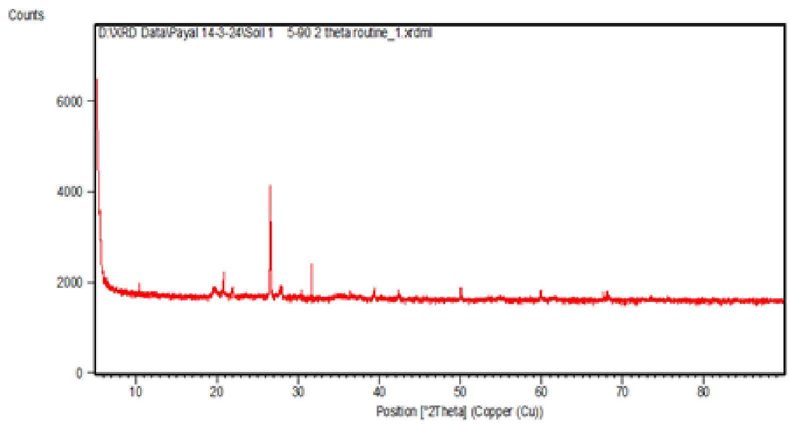

Figure.7. X-ray diffraction without NaCl

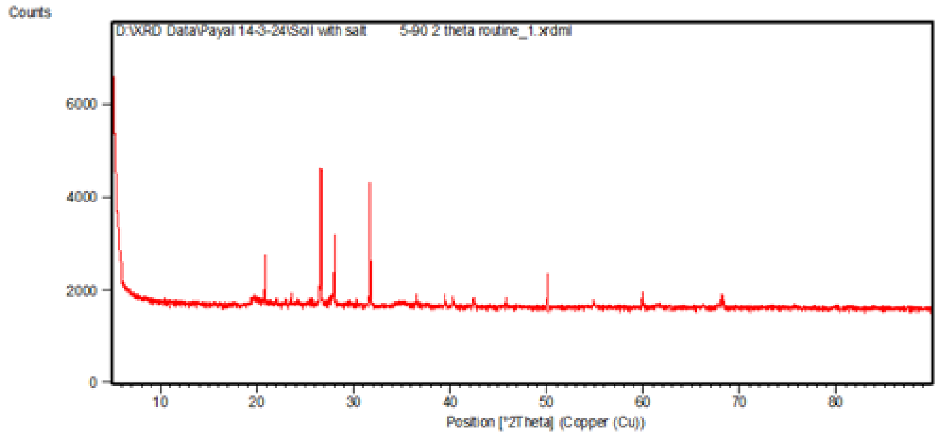

Figure.8. X-ray diffraction with NaCl

CONCLUSION

Common salt (NaCl) is an excellent soil stabilizer, and so in economic point of view it is better to use sodium chloride (NaCl) for stabilizing large area. The test finding show that as the percentage of common salt (NaCl) addition grow, soil properties including Maximum Dry Density and Optimum Moisture Content, s well as the Unconfined compressive strength and California Bearing Ratio value, improve. As a result we, can remark that 8% common salt (NaCl) addition is the best value for black cotton soil stability.

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