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Influence of Bio Enzyme and Expanded Polyethylene (EPE) Cushion on Swelling Characteristics of Expansive Soils

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Abstract: Expansive soils experience significant volume change associated with changes in moisture content. This volume change causes distortions to the structures resting on expansive soils. Documented evidence of the existence and problems associated with expansive soils are available. Several attempts are being made to control the swelling phenomenon of expansive soil, which is a major concern of the geotechnical engineering. So in this paper an attempt has been made to study the influence of Bio enzyme (terazyme)and EPE(Expanded polyethylene)cushion on swelling characteristics of expansive soils. An experimental programme has been planned and designed to quantify relatively the effect of Bio enzyme and EPE cushion layer on swelling characteristics by systematically varying all other factors over two different levels. The factors studied include Liquid Limit (W_L) and Dry Density (Υ_d) of soil, dosage of bio enzyme and thickness of EPE cushion. The study reveals that the effect of any given factor on Swelling Pressure and Swell potential is dependent on magnitude or level of other factors indicating that the effect of interaction among the factors is also significant. Regression models were developed for predication of swelling characteristics in terms of influencing and their interaction factors.
Key words: Expansive soils, Dry Density, Bio Enzyme, EPE cushion, , Swelling pressure, Swell potential

I. INTRODUCTION

Expansive soils are worldwide problematic soils they cause severe damage to the civil engineering structures. Expansive soils are found throughout many regions of the world, particularly in arid and semi-arid regions mostly in Africa, Tanzania, Sudan, Saudi Arabia, South Africa, The United States, China, Ethiopia, India, Spain, Jordon, Turkey, Iran, Mexico, etc. In India expansive soils occupies 20% of total geographical area. Mineralogical identification shows that Montmorrillonite is the predominant clay mineral present in expansive soils, which is responsible for high swelling. The swelling phenomenon is considered as one of the most serious challenges because of potential danger of unpredictable upward movement of structures. Swelling Pressure and Swell Potential are identified as important swelling characteristics which are required for assessment of heave and for safe and economic design of foundations resting on expansive soils.

II. MATERIAL PROPERTIES

A. Expansive Soils

Two types of expansive soils were collected for the present study one is from Kotala and other is from Renigunta airport around Tirupati in the state of Andhra Pradesh, India. The soils were collected 1.5m below the ground level. Samples of soils taken were air-dried and passed through IS425 micron. The basic geotechnical properties of the soils are presented in Table 1.

Table 1 Properties of the soils

Property	Kotala soil	Renigunta soil
Gravel, %	0	0
Sand, %	2.26	4.62
Silt + clay, %	97.74	95.38
Liquid Limit, %	56	98
Plastic Limit, %	29.5	27
Plasticity Index, %	26.5	71
Free Swell Index, %	90	230
I.S. classification	CH	CH

B. Bio Enzyme

Bio enzyme used in this study was Terazyme which is a natural, non-toxic liquid, formulated using vegetable extracts. They are perfectly soluble in water, brown in color with smell of molasses. Their aroma has no effect. Neither gloves nor masks are required during handling. Terrazyme is specially formulated to modify the engineering properties of soil. They require dilution in water before application. Terrazyme when added to water and mixed with soil alters the engineering properties depending upon the type of the soil and dosage of enzyme. These enzymes are liquid additives, which act on the soil to reduce the voids between soil particles and minimize absorbed water in the soil for maximum compaction. Properties of terazyme are presented in Table 2.

Table.2 Properties of Terrazyme (As per Avijeet Agencies, Chennai, India)

Identity	Bio- Enzyme (Terrazyme)
SECTION II - HAZARDOUS INGREDIENTS IDENTITY INFORMATION	
Hazardous Components	None
SECTION III - PHYSICAL/CHEMICAL CHARACTERISTICS	
Boiling Point:	212^{o}F
Specific Gravity:	1.05
Melting Point:	Liquid
Evaporation Rate:	Same as water
Solubility in Water:	Complete
Appearance/Odour:	Brown liquid, Non-obnoxious
SECTION IV - FIRE AND EXPLOSION HAZARD DATA	
Special Fire Fighting Procedures:	None
Unusual Fire/Explosion Hazards:	None
SECTION V - REACTIVITY DATA	
Unstable or Stable:	Stable
Conditions to Avoid:	Temperature above 45^{o}C (130^{o}F); pH below 3.5, above 9.5
Incompatibility (Materials to Avoid):	Caustics, Strong bases
Hazardous Polymerization:	Will NOT occur
SECTION VI - HEALTH HAZARD	
Route(s) of Entry:	Inhalation: None Skin: None Ingestion: None
Health Hazards (Acute and Chronic):	None
Carcinogenicity:	No
Signs and Symptoms of Exposure:	None
SECTION VII - PRECAUTIONS FOR SAFE HANDLING AND USE	
Steps To Be Taken If Material Is Released or Spilled:	Wash down with water
Waste Disposal Method:	Flush into any sewage system
Procedures To Be Taken In Handling and	Store at temperatures below 45oC
Storing:	(130^{o}F)
Other Precautions:	None
SECTION VIII - CONTROL MEASURES	
Respiratory Protection (Specific Type):	Not required
Working/Hygienic Practice:	Normal good practices

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C. EPE(Expanded polyethylene) Properties

EPE sheets are now a days used in construction for expantion joint fillers water proofing etc. EPE sheets are more flexible, chemical resistant , moisture resistant, low thermal conductivity non toxic and odourless. It can be used in temperature ranging from 40^o to 70^o , also tear strength upto 0.7kg/cm.it has tensile strength of 1.5-3.5kg/cm2 in transverse direction and 2.5-5.0 kg/cm2 in machine direction .Elongation at break of 50-70% in transverse direction and 80-100% in machine direction also it has compressive strength at 10% is 0.08-0.20 kg/cm2.

III. METHODOLOGY

In this research work specified tests were conducted to determine the Swelling Pressure and swell Potential of soil. Total of 28 Free Swell Oedometer tests are conducted as per IS 2720 Part XLI-1977 by varying Dry Density and Liquid Limit of soil bio enzyme dosage , thickness of EPE cushion. The details of the tests conducted are presented in Table 3 and Table 4.

Table 3 Details of tests conducted using bioenzyme

Soil used, W_L, %	Soil Dry Density Υ_d, kN/m^3	Bio Enzyme dosage(ml/kg)	No of Tests
56	14	0	3
		0.1	
		0.3	
	20	0	3
		3	
		6	
98	14	0	3
		3	
		6	
	20	0	3
		3	
		6	

Table 4 Details of tests conducted using EPE

Soil used, W_L, %	Soil Dry Density Υ_d, kN/m^3	EPE thickness (mm)	No of Tests
56	14	0	4
		3	
		6	
		10	
	20	0	4
		3	
		6	
		10	
98	14	0	4
		3	
		6	
		10	
	20	0	4
		3	
		6	
		10	

IV. RESULTS AND DISCUSSIONS

A total of 28Free Swell Oedometer tests are conducted by varying Liquid Limit and Dry Density of soil, dosage of terazyme and thickness of EPE cushion over two levels as per the details presented in Table 3 and Table 4. The test results obtained are presented in the form of graphs by plotting Thickness of sample against applied pressure on logarithmic scale in Fig. 1 to Fig8. .

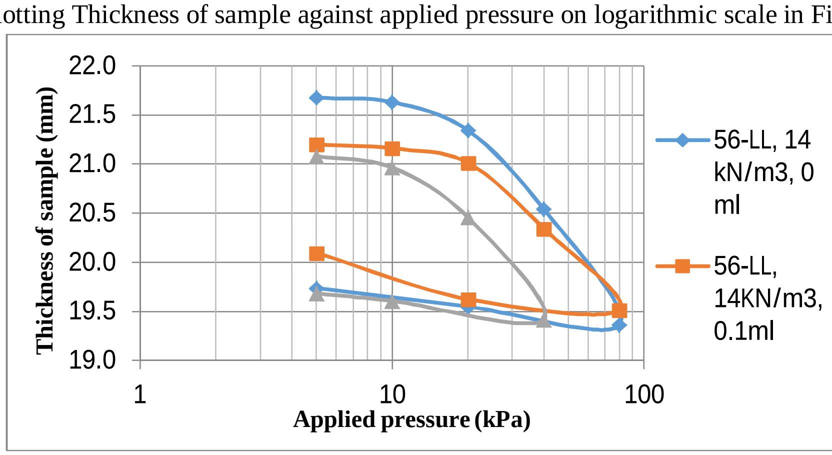

Fig. 1 Thickness of sample vs log p Curves of 56-LL soil with 14 kN/m^3 Density with Bio Enzyme

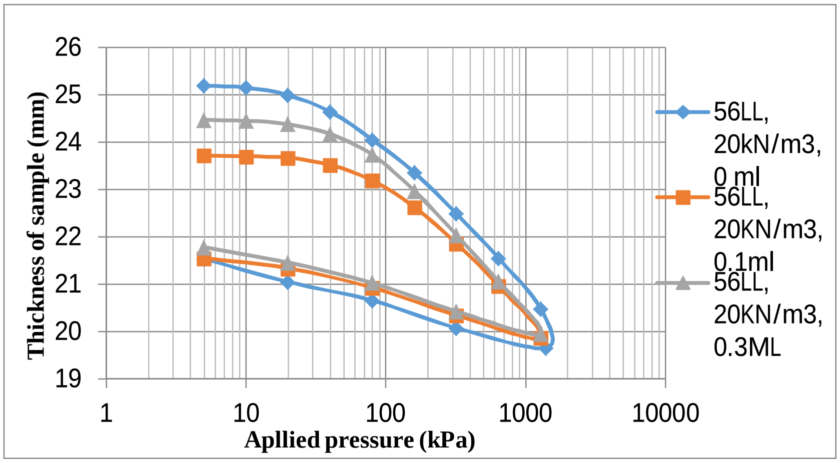

Fig. 2 Thickness of sample vs log p Curves of 56-LL soil with 20 kN/m^3 Density with Bio Enzyme

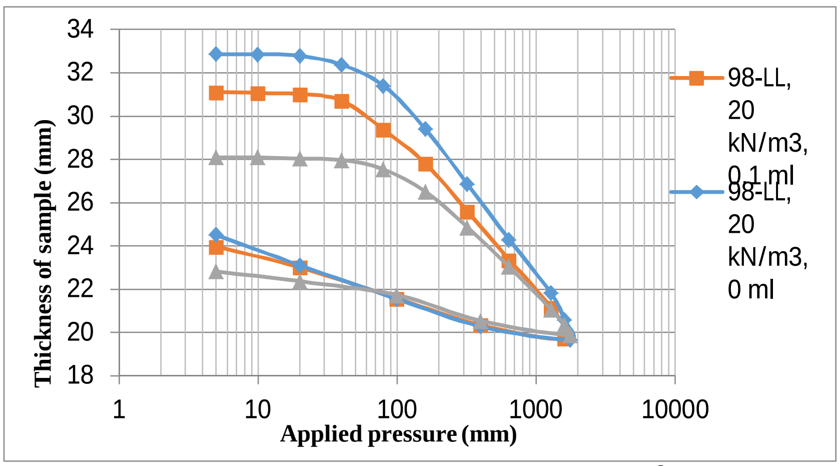

Fig. 3 Thickness of sample vs log p Curves of 98-LL soil with 20 kN/m^3 Density with Bio Enzyme

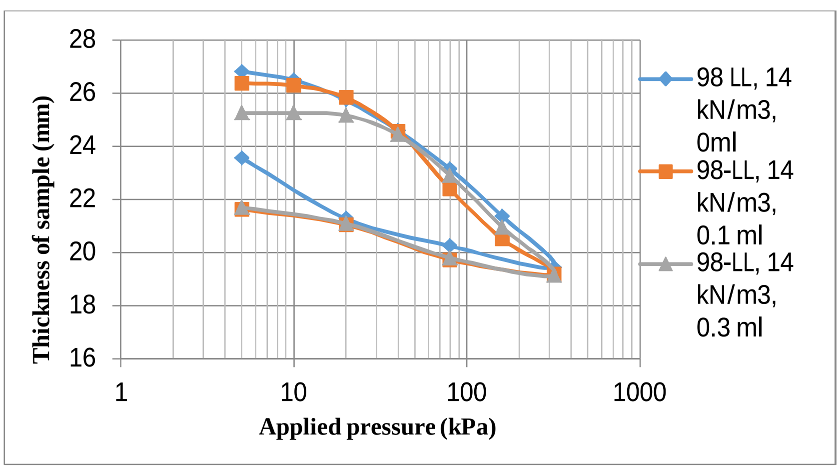

Fig. 4 Thickness of sample vs log p Curves of 98-LL soil with 14 kN/m^3 Density with Bio Enzyme

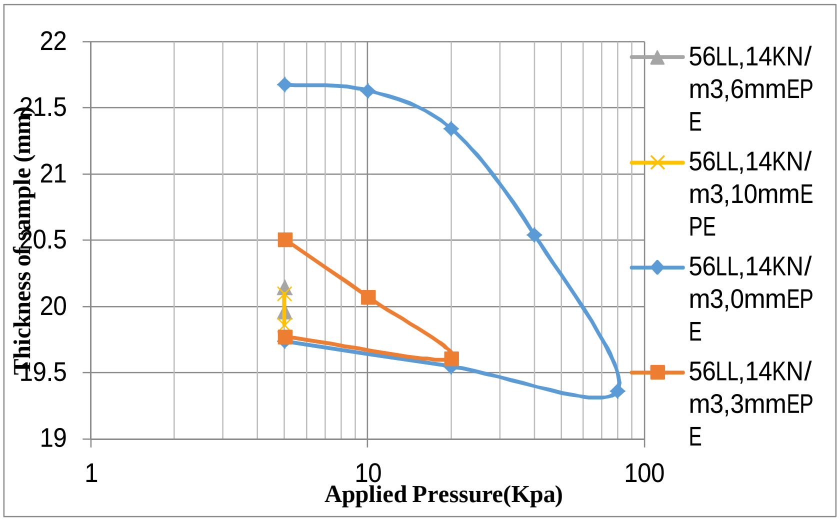

Fig 5 Thickness of sample vs log p Curves of 56-LL soil with 14 kN/m^3 Density with EPE

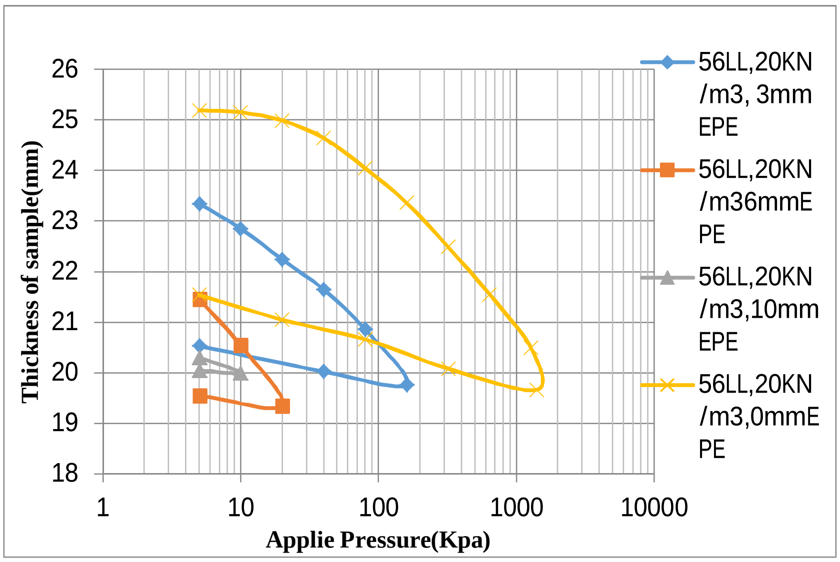

Fig 6 Thickness of sample vs log p Curves of 56-LL soil with 20 kN/m^3 Density with EPE

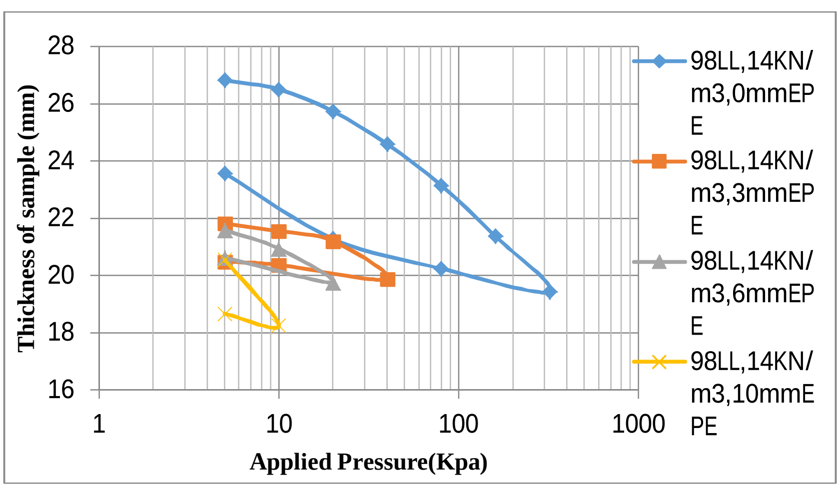

Fig 7 Thickness of sample vs log p Curves of 98-LL soil with 14 kN/m^3 Density with EPE

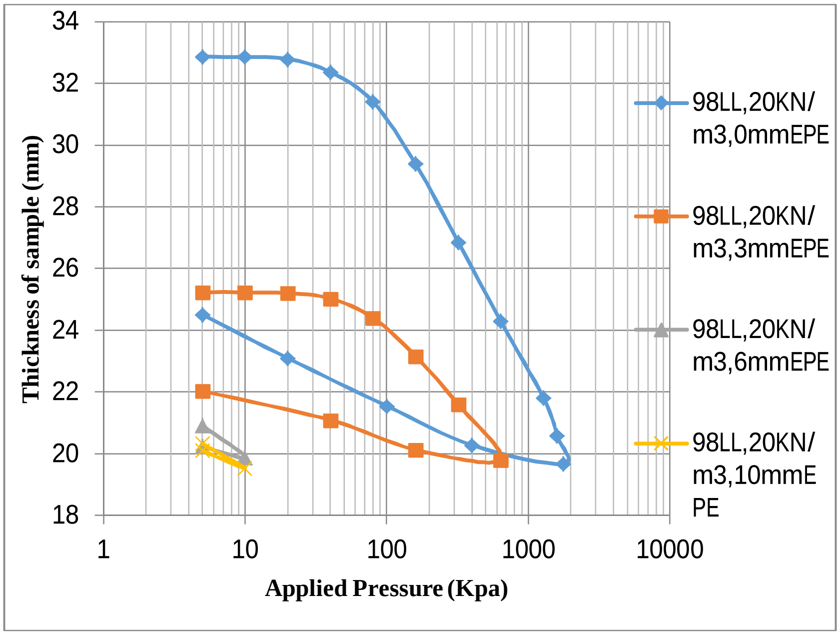

Fig 8 Thickness of sample vs log p Curves of 98-LL soil with 14 kN/m^3 Density with EPE

From the plots it is clear that Swelling Pressure is significantly varying, dependent on Liquid Limit and Dry Density of soil, Bio Enzyme dosage and thickness of EPE cushion. The Pressure corresponding to initial dial gauge reading on load increment curve is taken as the Swelling Pressure. Swelling Pressures so obtained are presented in Table 5 and Table 6

Table 5 Swelling Pressure of soils using Bio Enzyme

S. No.	Factor A W_L of soil (%)	Factor B γ_d of soil (kN/m^3)	Factor C Bio-Enzyme dosage (ml/Kg)	Swelling Pressure, p_s(kPa)	% Reduction in Swelling pressure
1	56	14	0	60	N.A
2	56	14	0.1	30	50
3	56	14	0.3	55	8.34
4	56	20	0	1300	N.A
5	56	20	0.1	1100	15.38
6	56	20	0.3	1200	7.69
7	98	14	0	270	N.A
8	98	14	0.1	210	22.23
9	98	14	0.3	240	11.12
10	98	20	0	1750	N.A
11	98	20	0.1	1600	8.57
12	98	20	0.3	1700	2.85

Table 6 Swelling Pressure of soils using EPE

S. No.	Factor A W_L of soil (%)	Factor B γ_d of soil (kN/m^3)	Factor C EPE (t) thickness (mm)	Swelling Pressure, p_s(kPa)	% Reduction in Swelling pressure
1	56	14	0	60	N.A
2	56	14	3	11.5	80.3
3	56	14	6	3	95.00
4	56	14	10	1	98.33
5	56	20	0	1300	N.A
6	56	20	3	155	88.08
7	56	20	6	16	98.77
8	56	20	10	10	99.23
9	98	14	0	270	N.A
10	98	14	3	40	85.19
11	98	14	6	19	92.96
12	98	14	10	16	97.78
13	98	20	0	1750	N.A
14	98	20	3	640	63.43
15	98	20	6	9.5	99.46
16	98	20	10	6.8	99.61

From Table 4 and Table 5 it is clear that Swelling Pressure increases with increase in Liquid Limit, soil Dry Density. As the soil Dry Density increases Swelling Pressure increases. To minimize this Swelling Pressure Bio enzyme (terazyme) and in other cycle EPE cushion is added by varying terazyme dosage and in another cycle by varying EPE thickness. By adding bio enzyme aswellas EPE Swelling Pressure reduction is significant at high Density, less at low Density. So to reduce the Swelling Pressure value at high Density bio enzyme dosage and EPE thickness is changed from 0ml/kg,0.13 ml/kg, 0.3 ml/kg and 0mm,3mm,6mm,10mm

A. Influence of BioEnzyme (Terazyme)

Swelling Pressure Vs Bioenzyme dosage plot is drawn below. From the graph it is clear that Swelling Pressure is reducing with respect to dosage of Terazyme up to some extent after dosage increases swelling pressure also tends to increase by 15.38 percent for Kotala sample and 8.57 percent for Renigunta sample for soil Dry Density of 20 $kN/m^3$with Bio enzyme of 0.1ml/kg. The graph shows that at 0.1ml it reducing and again increasing for 0.3ml/kg dosage

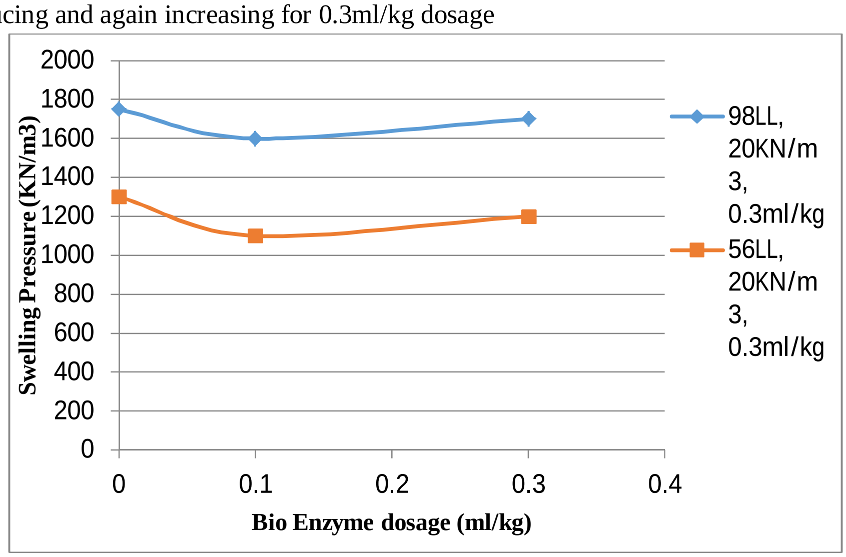

Fig. 9 Swelling Pressure Vs Bio Enzyme Dosage plot for soil Dry Density of 20 kN/m^3 with 0.3ml/kg

B. Influence of EPE(Expanded polyethylene)

And Swelling Pressure Vs EPE thickness plot is drawn below . From the graph it is clear that Swelling Pressure is reducing with respect to EPE thickness . Swelling Pressure is reduced by 99.2 percent for Kotala sample(56 W_L) and 99.6 percent for Renigunta sample(98 $W_{L)}$ for soil Dry Density of 20 kN/$m^3$with EPE thickness of 10mm.

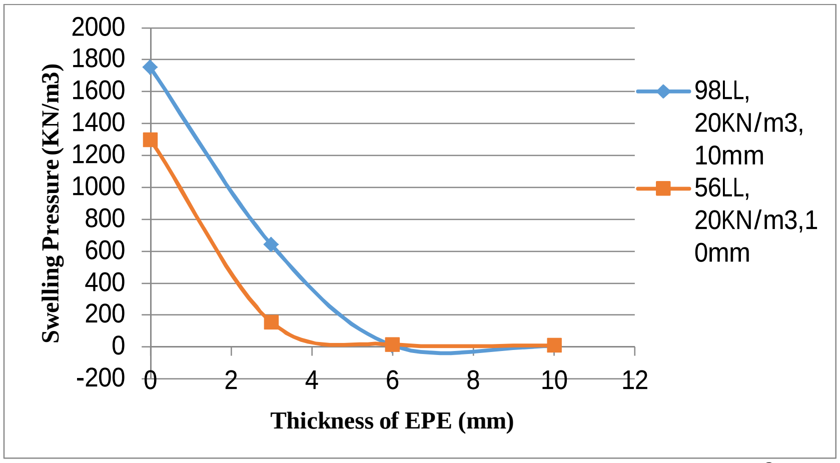

Fig.10 Swelling Pressure Vs Bio Enzyme Dosage plot for soil Dry Density of 20 kN/m^3 with 10mm thickness

C. Swelling Potential

One of the objectives of the present investigation is to study the effect of bioenzyme and also EPE on Swelling Potential. To meet this objective the parameters considered for this study are Liquid Limit of soil, Dry Density of soil, dosage of bioenzyme and EPE cushion. Total of 28 tests are conducted to study the effect of bio enzyme and EPE cushion on Swelling Potential. The results pertaining to these 28 experiments are presented in the form of plots from Figure 1 to Figure 8.From the plots Figure 1 to Figure 8 maximum heave corresponding to the 5kPa load divided by the initial thickness of sample is reported as Swelling Potential. The Swell Potential of all the tests conducted are obtained and reported in Table 7 and Table 8.

Table 7 Swelling Potential of Soils using Bio Enzyme

S. No.	Factor A W_L of soil (%)	Factor B γ_d of soil (kN/m^3)	Factor C Bio Enzyme dosage (ml/kg)	Swell Potential, S_p(kPa)	% Reduction in Swell Potential
1	56	1.4	0	8.38	N.A
2	56	1.4	0.1	5.40	35.56
3	56	1.4	0.3	6	28.40
4	56	2	0	25.95	N.A
5	56	2	0.1	18.60	28.32
6	56	2	0.3	22.35	13.87
7	98	1.4	0	34.10	N.A
8	98	1.4	0.1	31.95	6.30
9	98	1.4	0.3	26.30	22.87
10	98	2	0	64.33	N.A
11	98	2	0.1	55.56	13.87
12	98	2	0.3	40.50	30.25

Table 8 Swelling Potential of Soils using EPE

S. No.	Factor A W_L of soil (%)	Factor B γ_d of soil (kN/m^3)	Factor C EPE (t) thickness (mm)	Swell Potential, p_s(kPa)	% Reduction in Swell Potential
1	56	14	0	8.38	N.A
2	56	14	3	2.55	69.57
3	56	14	6	0.65	92.24
4	56	14	10	0.48	94.27
5	56	20	0	25.95	N.A
6	56	20	3	16.71	35.61
7	56	20	6	7.27	71.98
8	56	20	10	1.51	94.18
9	98	14	0	34.10	N.A
10	98	14	3	9.08	73.37
11	98	14	6	7.95	76.69
12	98	14	10	2.73	91.99
13	98	20	0	64.33	N.A
14	98	20	3	26.16	59.33
15	98	20	6	24.92	61.26
16	98	20	10	20.99	67.37

From Table 7 and Table 8 it is clear that Swelling Potential increases with increase in soil Dry Density and Liquid Limit of soil. Bio enzyme as well as EPE minimizes the Swelling Potential of soil. This Swelling Potential is very high for 20 kN/m^3 soil Dry Density. So dosage of Terazyme as well as EPE cushion is varied from 0ml/kg, 0.1ml/kg, 0.3ml/kg and 0mm,3mm ,6mm,10mm for soil Dry Density of 20 kN/m^3. Swelling Potential is reduced by64.43 percent and 71.67 percent for Kotala sample and Renigunta sampe with 14 kN/m^3 and 14 kN/m^3 soil Dry Density by adding 0.1ml/kg bio enzyme. Swelling Potential is reduced by 71.59 percent and 77.12 percent for Kotala sample and Renigunta sample with 20 kN/m^3 and 20 kN/m^3 soil Dry Density by adding 0.1ml/kg bio enzyme and . Swelling Potential is reduced by 5.73 percent and 5.82 percent for Kotala sample and Renigunta sample with 14 kN/m^3 and 14 kN/m^3 soil Dry Density by adding 10mm EPE. Swelling Potential is reduced by 2.56 percent and 8.00 percent for Kotala sample and Renigunta sample with 20 kN/m^3 and 20 kN/m^3 soil Dry Density by adding 10mm EPE **.**

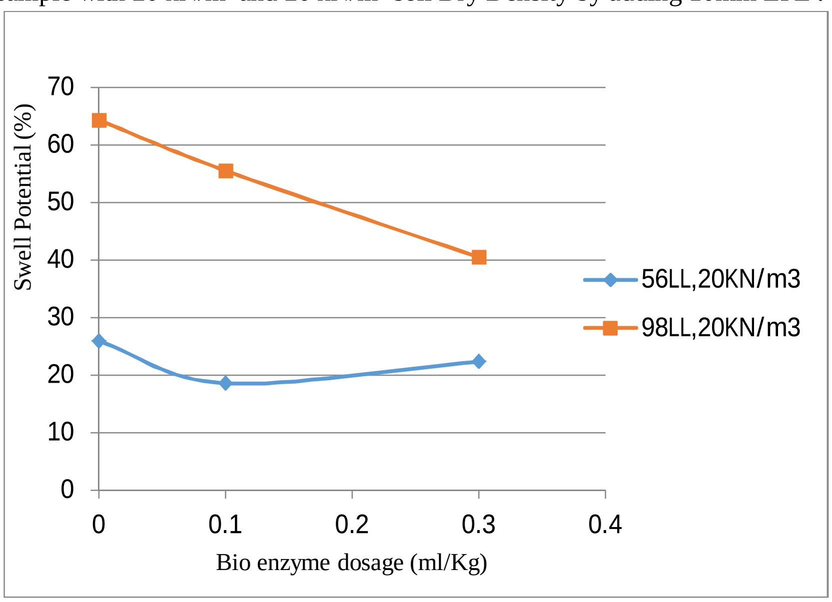

Fig. 11 Swelling Potential Vs Bio Enzyme Dosage plot for soil Dry Density of 20 kN/m^3 with 0.3ml/kg

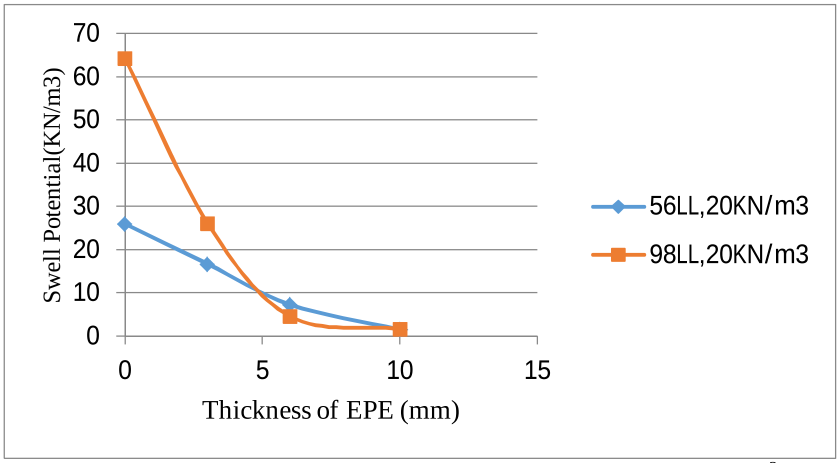

Fig. 12 Swelling Potential Vs Thickness of EPE plot for soil Dry Density of 20 kN/m^3 with 10mm

D. Time Rate of Heave

Heave is the amount of swell observed in Free Swell Oedometer test after placing a 5 kPa load and allowed it swell freely. Potential swell of a given soil is Swell Potential which is evaluated for all the 28 tests conducted and presented in previous section. Swelling or heaving is a time dependent process and Swell Potential do not give any idea of time rate of Swelling. Heaving of soil in Free Swell Oedometer tests were measured at regular interval of time. These results are presented graphically in the form of Heave vs lot t plots and the same are shown in Figures 13, 14, 15 and 16 for bioenzyme and figures 17, 18, 19, 20.

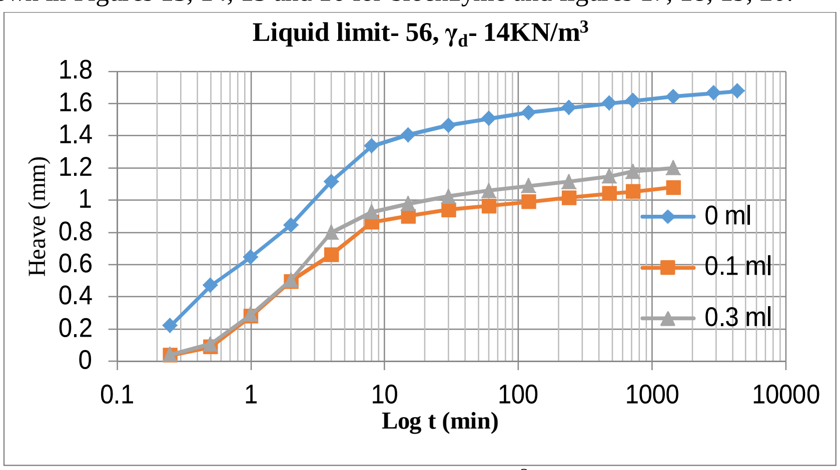

Fig.13 Heave Vs time plot for 56 W_L soil with 14 kN/m^3 soil Dry Density using Bio Enzyme

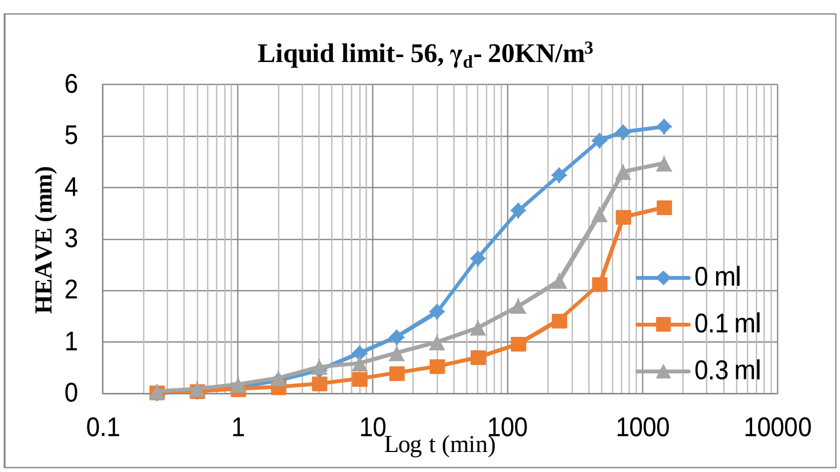

Fig 14 Heave Vs time plot for 56 W_L soil with 20 kN/m^3 Dry Density using Bio Enzyme

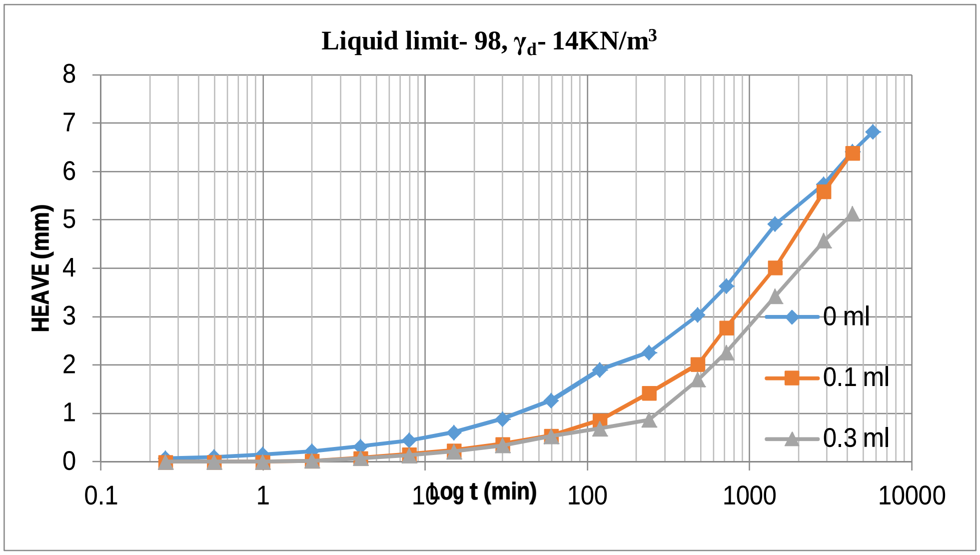

Fig 15 Heave Vs time plot for 98 W_L soil with 14 kN/m^3 Dry Density using Bio Enzyme

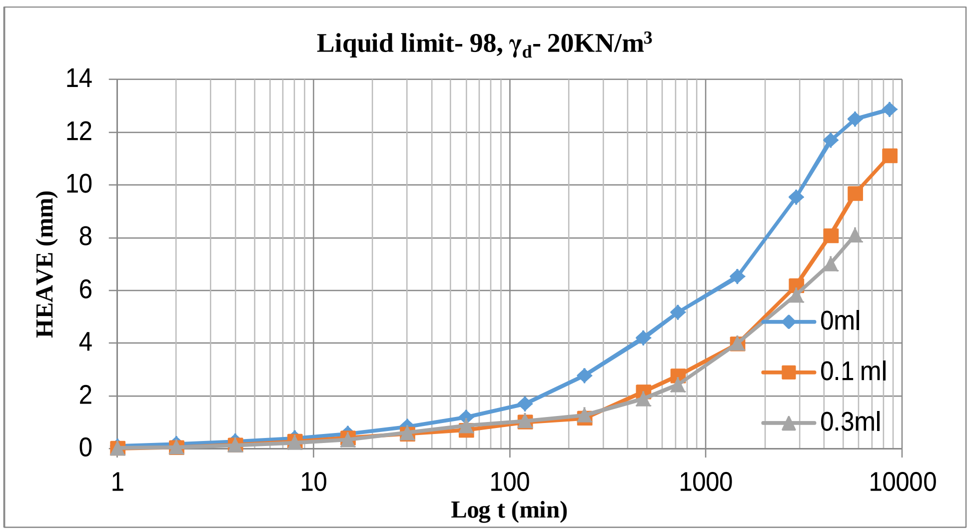

Fig. 16 Heave Vs time plot for 98 W_L soil with 20 kN/m^3 Dry Density using Bio Enzyme

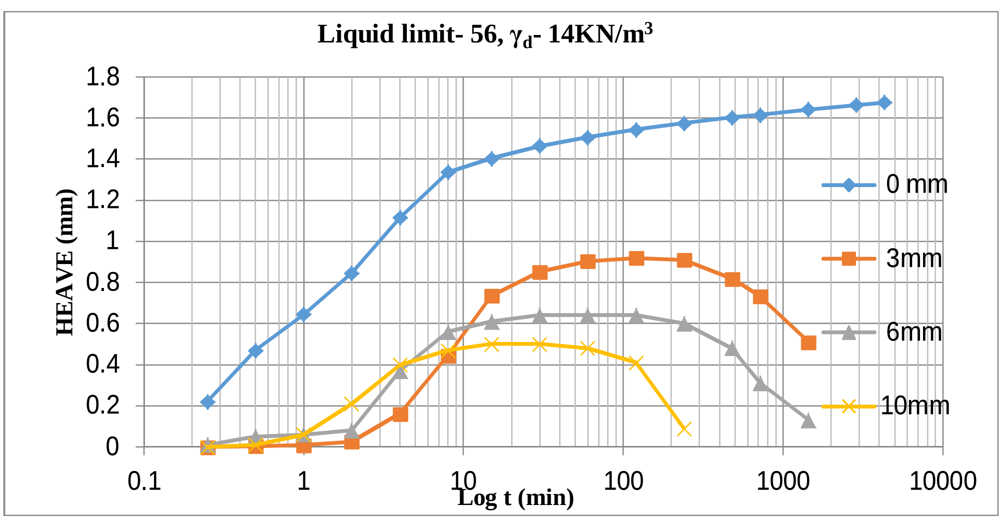

Fig.17 Heave Vs time plot for 56 W_L soil with 14 kN/m^3 soil Dry Density using EPE

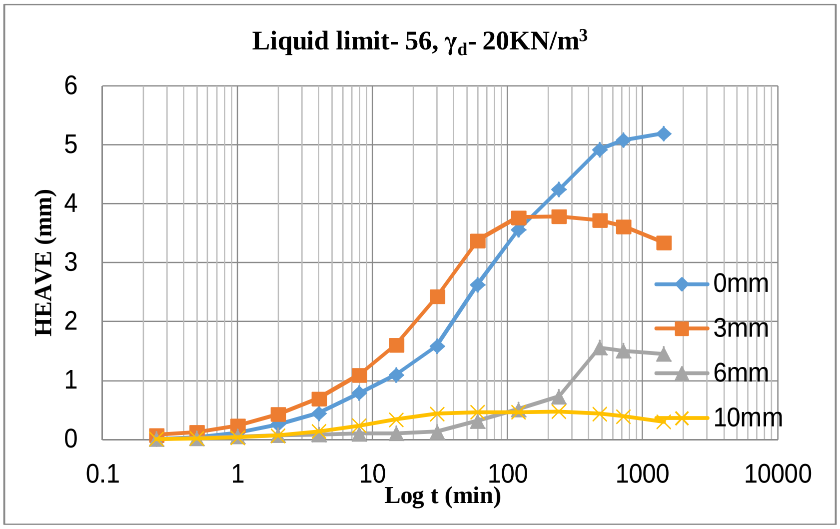

Fig.18 Heave Vs time plot for 56 W_L soil with 20 kN/m^3 soil Dry Density using EPE

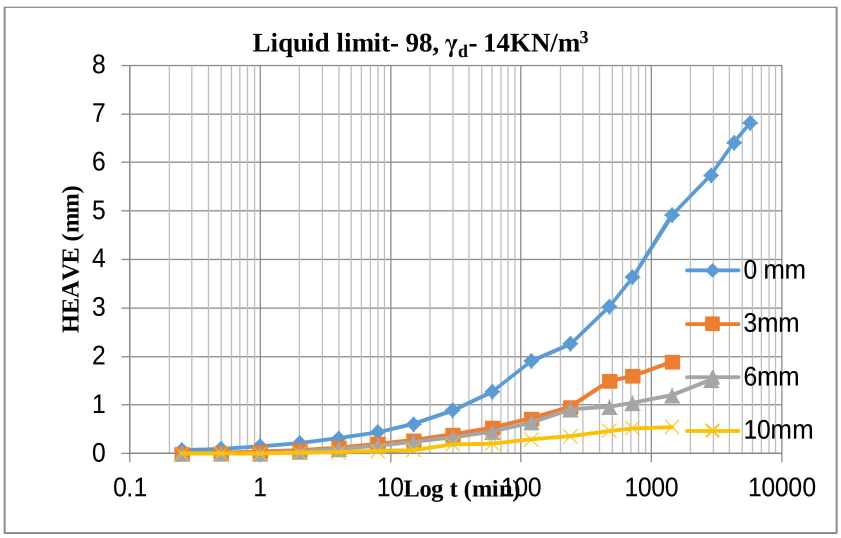

Fig.19 Heave Vs time plot for 98 W_L soil with 14 kN/m^3 soil Dry Density using EPE

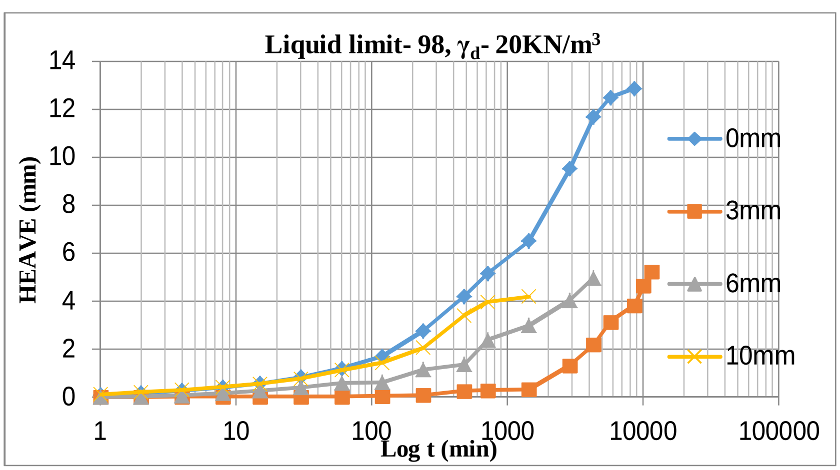

Fig.20 Heave Vs time plot for 98 W_L soil with 20 kN/m^3 soil Dry Density using EPE

From above plots following observations are made. From Figure 12 it can be said that, for low Liquid Limit and low Density heaving is observed or initiated immediately after commencement of the test. Magnitude of time for initiation of steep heaving is varies from 15 seconds to one hour. As the Density and Liquid Limit increases starting time for heaving is also increases. From Figures 13, 14 ,15 it is observed that starting time for heaving is 4 minutes for soil of low Liquid Limit and high Density,8-10 minutes for high Liquid Limit with low Density and 60 minutes for high Liquid Limit soil with high Density. After initiation of heave steep raise in heaving is observed then it becomes asymptotic, i.e. completes heaving. There is relatively less effect of Bio enzyme on time- rate of heave for low Density soil. But this effect is significant on time-rate of heave for soil of high Density. Magnitude of time for steep heaving is is relatively high for high Liquid Limit soil .By addition of BioEnzyme this time rate of heaving is reduced significantly. From Figures 17, 18, 19 it is observed that starting time for heaving is 10 minutes for soil of low Liquid Limit and high Density,10-30 minutes for high Liquid Limit with low Density and 15-60 minutes for high Liquid Limit soil with high Density. After initiation of heave steep raise in heaving is observed then it becomes asymptotic, i.e. completes heaving . There is relatively Equal effect of Bio enzyme, W_L, γ_d on time- rate of heave for low Density and high density soil. But this effect is significant on time-rate of heave for soil of high Density. Magnitude of time for steep heaving is is relatively high for high Liquid Limit soil .By addition of EPE this time rate of heaving is reduced significantly.

V. CONCLUSIONS

This paper presents an experimental study on influence of Bio Enzyme and EPE cushion on swelling characteristics of expansive soils by conducting a series of Free Swell Oedometer tests in the laboratory. Based on the experimental results following conclusions are drawn.

A. Swelling Characteristics are namely Swelling Pressure, Swell Potential are significantly influenced by Bio Enzyme and EPE cushion and can modify the Swelling characteristics by adding Bioenzyme and EPE cushion.
B. Swelling Pressure is reduced by 15.38 percent for Kotala sample and by 8.57percent for Renigunta sample by adding Bio enzyme of 0.3ml/kg for 20 kN/m^3 soil Dry Density.
C. Swelling Pressure is reduced by 2.56 percent for Kotala sample and by 8 percent for Renigunta sample by adding EPE cushion of 10mm for 20 kN/m^3 soil Dry Density
D. Swelling Potential is reduced by 8.57 percent for Kotala sample and 15.38 percent for Renigunta sample by adding Bio enzyme of 0.3ml/kg for 20 kN/m^3 soil Dry Density.
E. Swelling Potential is reduced by 99.2 percent for Kotala sample and 99.6 percent for Renigunta sample by adding EPE cushion of 10mm for 20 kN/m^3 soil Dry Density
F. Bio Enzyme and EPE can effectively reduce the heave depending on the dosage of Terazyme and EPE cushion thickness and soil Dry Density adopted.
G. EPE cushion thickness give significant decrease in swell potential and swelling pressure for high and low Liquid limit. But by adding bio enzyme for high Liquid limit based on increase in dosage swelling pressure also will increase but swell potential reduces significantly.it is because of terazyme bonding of soil will takes place and it takes more load to regain its original thickness even it swell less.
H. We can further we have scope to continue this project by varying soil dry density and varying EPE thickness or Bio enzyme .

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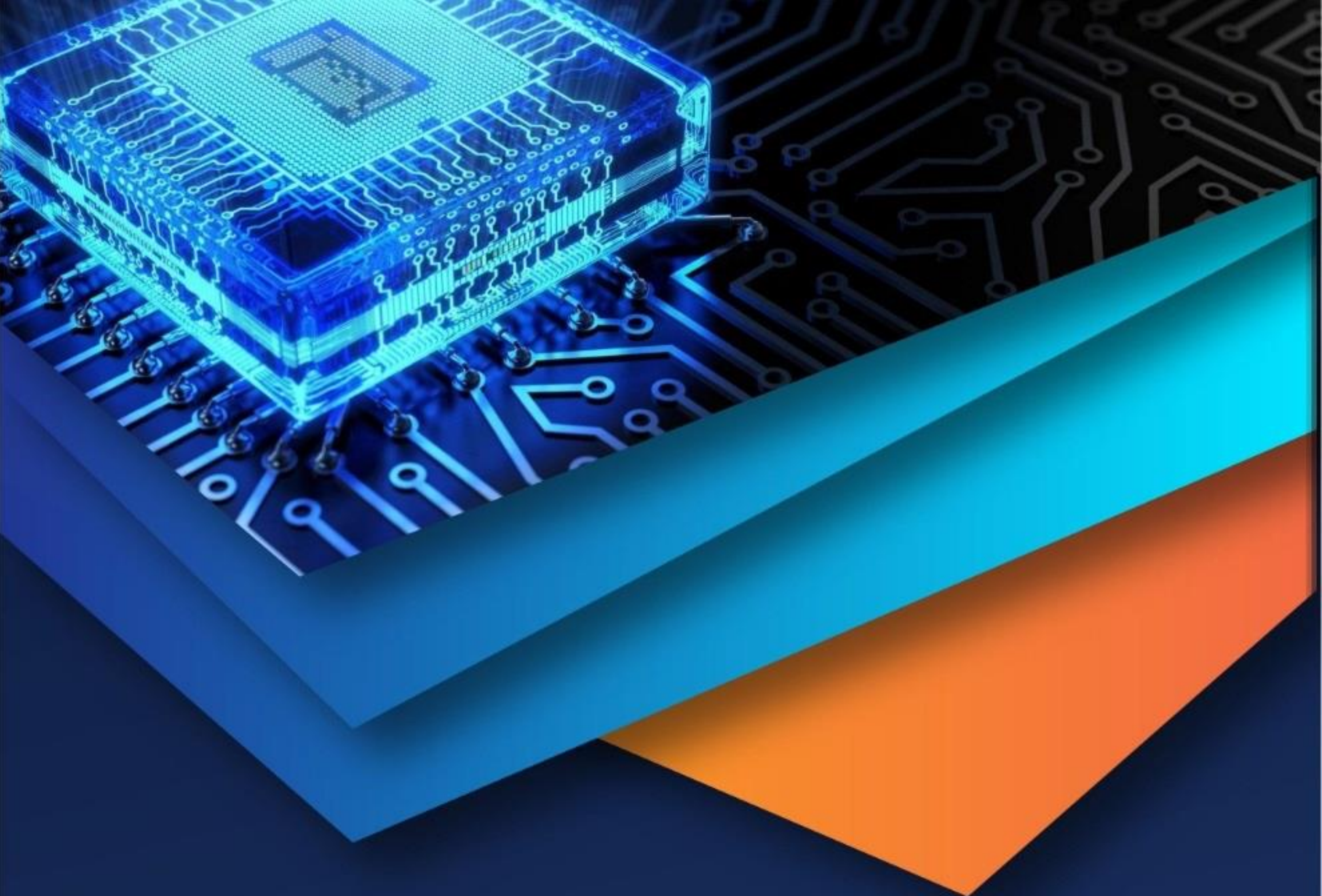

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