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Comparing and Suggesting the Remedial Measures for Construction of Multistoried Building in Clayey Soil

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Abstract: Site located in Narayangaon is proposed for 3 residential and 2 commercial buildings. For the construction of its foundation initially the type of soil was classified using IS classification. Due to expansive nature of the soil various remedial measures of soil stabilization were studied. Laboratory tests of soil were performed. Mixture of fly-ash and steel slag with soil was made in proportion of 5%, 10%, 15%, 20% respectively was made and laboratory tests were performed on soil. Tests like moisture content, liquid limit, plastic limit, dry density, optimum moisture content, free swell and California bearing ratio were done, to study the characteristics of black cotton soil. Taking into considerations all the above factors, pile foundation technique was suggested. The piling operation for a particular residential building was done by the traditional method which cost Rs 4300000/-. The piling operation for other adjacent building of similar area was planned and the cost and time of the operation was saved.

***Keywords*: Expansive soil; black cotton soil; pile foundation; steel slag; flyash; soil stabilization.**

I. INTRODUCTION

Narayangaon is located in Pune district at 110 Km from Pune. It is situated at busy Pune-Nasik highway. It is one of important political/ economic zone in Pune district. Previous area is used for agricultural activity but now days due to increase in population heavy civil engineering activities are going on. During such activities it is proposed to construct a residential and commercial project on survey no 291, 293, 296, 297, and 300.

Normally the soil occurring at that area is Black Cotton soil according to the soil survey department. To treat such soil there are number of traditional methods used like soil lime stabilization/ Soil cement stabilization, etc. but on the other hand they are very costly and time consuming. To have additional view in treating such soil with industrial waste this is generated nearby. It is also proposed to use industrial waste like fly ash & steel furnace slag to improve its properties.

First the soil investigation should be done thus to identify the type of soil, engineering properties of soil.

Building construction over tropical black clays generally poses a major problem due to the ability of the soils to swell and shrink considerably with changes in moisture content, which consequently lead to low bearing values when wet and severe cracking when dry. Also, geotechnical and index properties of these materials indicate a classification that connotes inadequacy for use as a subgrade material.

Expansive soils in India are named "Black Cotton Soil." These tropical black clays range from light gray to dark gray and black in color. The name has been given because of their black color and great suitability for growing cotton. Thus the terms tropical black clay and black cotton soil can be used inter- changeably. This group is characterized by the presence of montmorillonite in the mineralogy which is capable of large volume changes from the dry to the saturated state. When wet they swell and exert high swelling pressures.

Black cotton soils are poor materials to employ in building and highway or airfield construction because they contain high percentages of plastic clay. In areas where they occur, usually there is no suitable natural gravel or aggregates and most deposits cover significantly large areas that avoiding them is not possible.

Conventionally lime and Portland cement have been used to appreciably improve the properties of black cotton soils to make them meet the requirements for construction works. While this significantly improves the properties of the material, the cost of incorporating the additives is prohibitive. Subsequently, research has focused on potentially cost effective materials such as fly ash , blast furnace, etc. that can improve the properties of deficient soils.

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the line particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during

combustion of coal. F1y ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is jointly known 115 coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata.
Steel slag, a by-product of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling.

II. RESEARCH SIGNIFICANCE

As discussed earlier if the properties of the soil present are weak that is if the bearing capacity of the soil is weak then there are certain measures that can be adopted to improve the property of that particular soil by the means of stabilization or by adopting pile foundation
As there are many ways that the particular soil can be stabilized, also there are many ways of doing pile foundation, it is utmost important that, which type of stabilization or pile foundation to be used, taking into consideration suitability, reliability, economy, speed of work, etc.

III. OBJECTIVES

A. Testing of the soil samples which are available on the site.
B. Testing the rock samples which are recovered at the time of boring.
C. Testing the quality and other properties of the water present on site.
D. Comparing different types of stabilizing methods that can be adopted taking into consideration all the factors.
E. Suggesting the appropriate method which will be used on the site.
F. Managing the work.
G. Completing the work before time and attaining economy.

IV. TEST METHODOLOGY

Various test considered on natural soil with various proportions of fly ash & steel slag

A. Particle size distribution
B. Liquid limit
C. Plastic limit
D. Water content
E. Free Swell
F. Compaction test (Standard proctor test)
G. California Bearing Ratio test

1) Project Description: It is proposed to construct five buildings as follows
Residential 3 buildings. Parking + seven storied
Commercial 2 buildings one basement, ground + five storied
Height of building is 24m
Loading varies from 200-500 kN/m².
Description of Subsurface Condition
Details of subsurface conditions for this project are given in borehole logs & are discussed below based on drilling and sampling in two boreholes. Generalized sub-soil profile for the area investigated can be classified as follows:
a) Blackish to brownish stiff clayey silt
b) Brownish dense silt sand
c) Greyish moderately to slightly weathered moderately fractured Amygdaloidal basalt.
Following table provides thickness in metres& RQD (Rock Quality Designation) in % & SPT N value range for layers mentioned above.

Table no 1- thickness, RQD & SPT values for layers of borehole.

Bore hole no.	Layer I		Layer II		Layer III	
	Thick (m)	SPT (N) value	Thick (m)	SPT(N) value	Thick (m)	RQD (%)
BH1	9.47	10-43	-	-	2.55	52-77
BH2	8.70	12-19	0.79	39	2.53	82-97

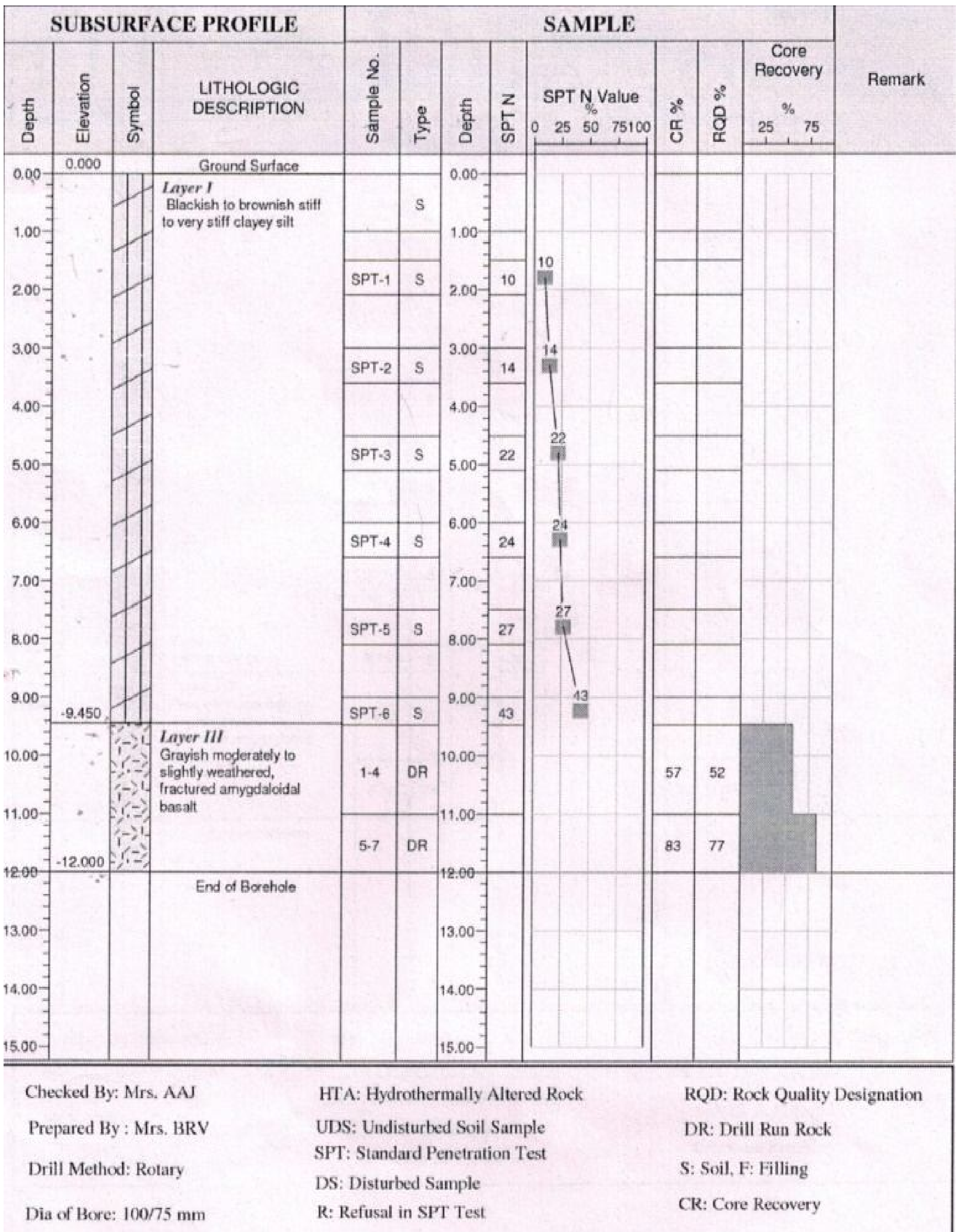

Fig 1- Subsurface profile for bore hole 1

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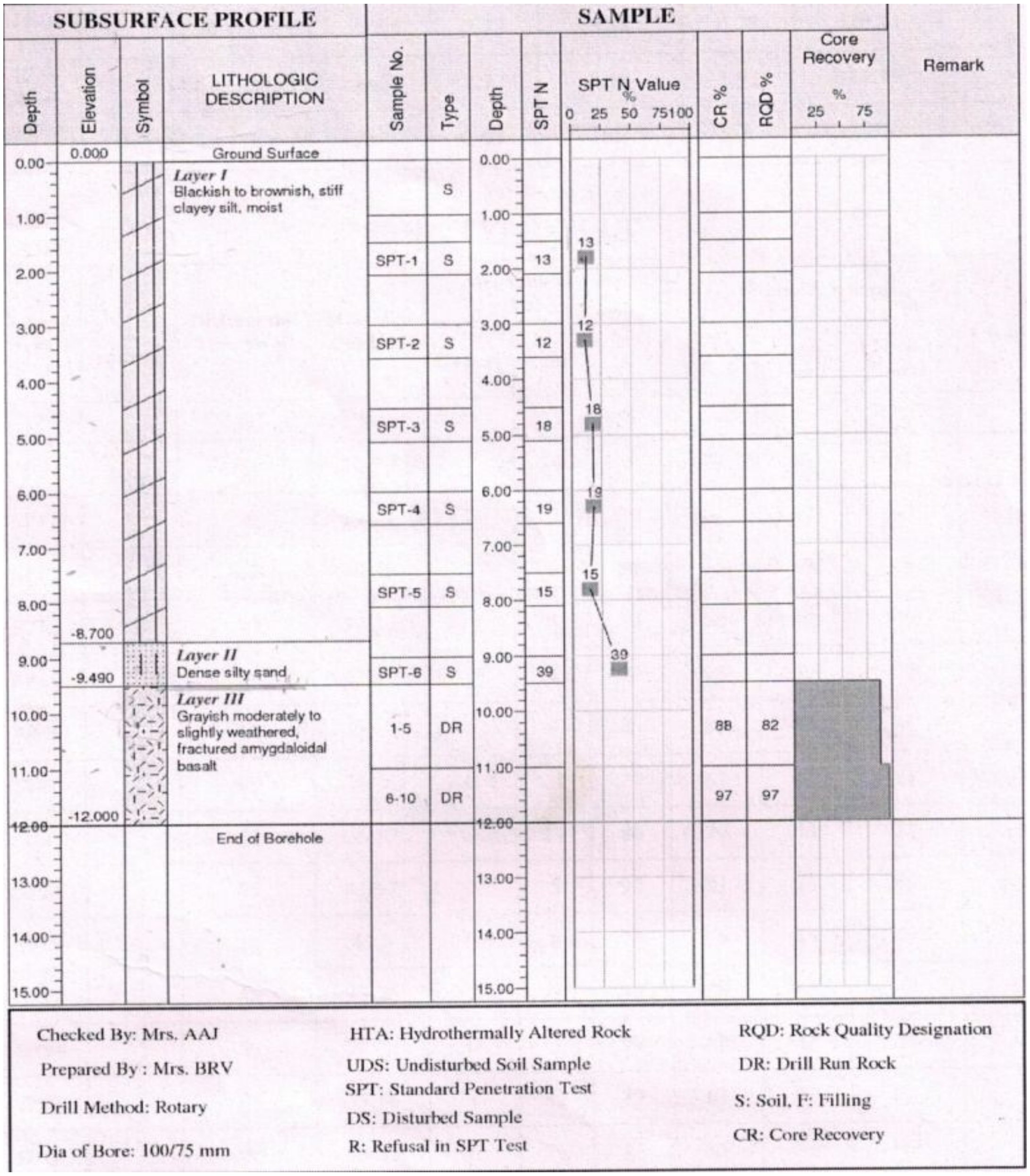

Fig 2- Subsurface profile for bore hole 2

H. Water Level

Water level was noted after 24 hour of drilling shows to 7.5m depth in the boreholes. The water level noted may not reflect correct ground water levels. As the correct method to determine ground water table is to install sand pipe piezometer and monitor over long period of time. Seasonal and annual fluctuations in ground water levels are expected.

I. Laboratory Testing

Laboratory tests were performed on selected samples to evaluate relevant engineering soil properties. Laboratory rests include moisture content, sieve analysis, Atterberg's limits & differential free swell in soil & water absorption, porosity, density, compressive strength on rock samples.

J. Chemical Analysis of Water & Soil

Chemical test like pH, chloride, sulphate are conducted on water & soil samples. The test results are as follows.

Table no 2- chemical analysis of water

BH no.	pH	Chloride (ppm)	Sulphates (ppm)
BH-1	7.42	102.13	202.37

Table no 3- chemical analysis of soil

BH No.	Depth of sample	pH	Chloride (%)	Sulphates (%)
BH-1	3.0-3.6	7.27	0.071	0.082
BH-1	9.0-9.47	7.11	0.078	0.110
BH-2	0.0-1.0	7.0	0.085	0.098

K. Summary of Laboratory Test Results

Table no 4- rock test result

BH No.	Depth (m)	PC No.	Avg. dia Of core (mm)	Avg. height Of core (mm)	Density (kg/m_3	Sp. Gr	Water Absorption (%)	Porosity (%)	Unconfined Comp. Strength (kg/cm2)
1	10.4-11.0	4	55.00	108.69	2611	2.82	0.60	1.68	535.74
	11.0-12.0	7	54.49	106.08	2669	2.73	2.48	6.78	470.15
2	10.0-11.0	5	54.65	105.11	2662	2.72	2.18	5.93	344.79
	11.0-12.0	10	54.89	106.68	2679	2.91	1.81	5.26	326.70

Table no 5- Soil test result

BH No.	Sample Type	Depth of Sample	Differential free swell	Moisture content	Mechanical sieve analysis			Atterberg's limit			IS classification
					Gravel	Sand	Silt & clay	Liquid Limit	Plastic Limit	Plasticity Index	
			%	%	%	%	%	%	%	%	
1	DS	0.0-1.0	60	34.29	1	10	89	79	38	41	MH
	SPT1	1.5-2.1	50	29.07	2	9	89	84	41	43	MH
	SPT2	3.0-3.6	64	40.35	2	6	92	95	47	45	MH
	SPT3	4.5-5.1	50	37.11	13	4	83	88	42	43	MH
	SPT4	6.0-6.6	45	42.69	3	4	93	98	39	26	MH
	SPT5	7.5-8.1	45	41.02	5	9	86	89	43	43	MH
	SPT6	9.0-9.47	18	34.26	0	21	79	63	42	21	MH
2	DS	0.0-1.0	52	26.87	3	11	86	74	43	31	MH
	SPT1	1.5-2.1	55	41.97	3	5	92	81	36	45	MH
	SPT2	3.0-3.6	50	41.8	14	8	78	56	45	11	MH
	SPT3	4.5-5.1	45	33.36	2	8	90	88	42	46	MH
	SPT4	6.0-6.6	50	27.88	0	5	95	88	45	23	MH
	SPT5	7.5-8.1	25	35.56	1	12	87	63	39	24	MH
	SPT6	9.0-9.43	05	15.	6	79	15	NP	NP	NP	SM

V. RESULT AND DISCUSSION

A. *Classification of Natural Soil*

Liquid limit-74.5percent
Plastic limit- 34.5percent
Therefore plasticity index = liquid limit – plastic limit
= 74.5 -34.5
= 39

From A- line graph and particle size distribution result, 74.5 i.e. liquid limit & Plasticity Index. = 39%, therefore classification of soil is MH.
M = silt
H = High compressibility

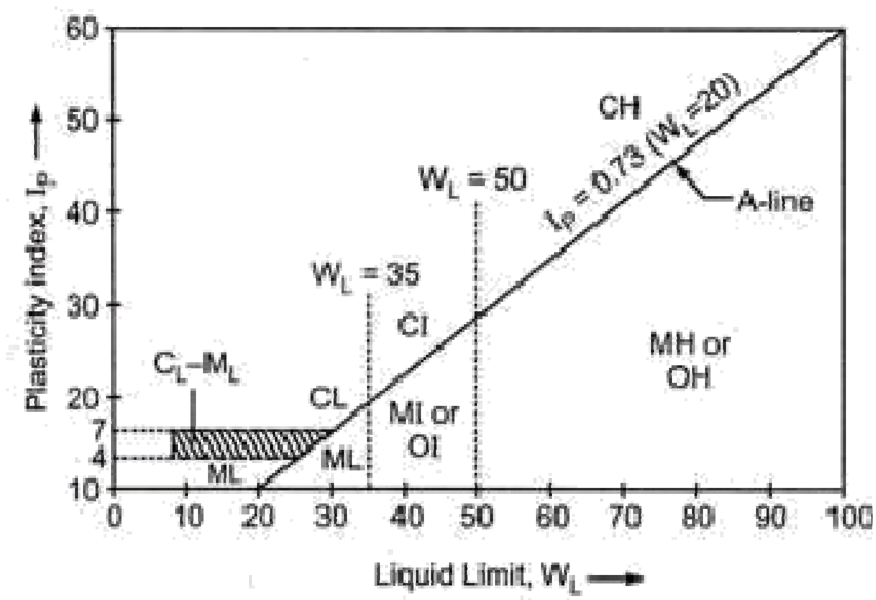

FIg 3:- plasticity chart (is classification system)

B. *Moisture Content*

This test is conducted on natural soil and by mixing fly ash & steel slag in four proportions separately.
Moisture content of natural soil- 20.17percent
Moisture content after adding Fly Ash & Steel Slag

Table 6.1:- moisture content for fly ash

Fly ash	5%	10%	15%	20%
Water content percentage	17.26	15.26	11.17	8.13

Table 6.2:- moisture content for steelslag

Steel slag	5%	10%	15%	20%
Water content percentage	20.10	19.8	19.3	19

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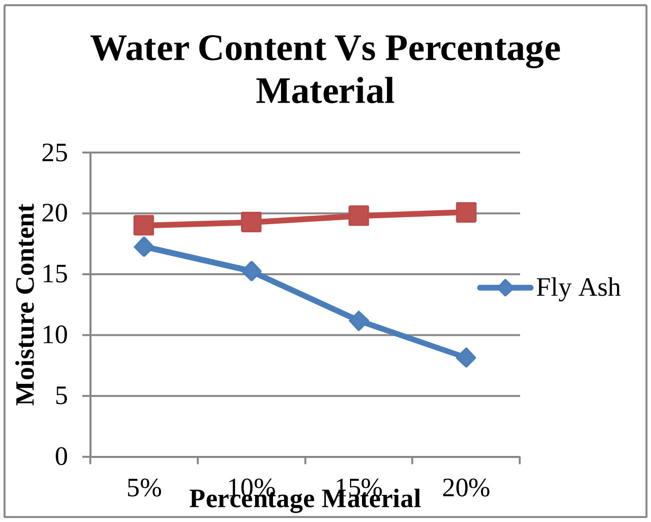

Fig 4- Graph representing Water content Vs. Percentage material

As % of fly Ash increase in soil mix then % water content in soil decreases from 20.17% to 8.13%. As % of steel slag increase in soil mix then no significant decrease in water content criteria.

C. Liquid Limit

This test is conducted on natural soil and by mixing fly ash & steel slag in four proportions separately.

Liquid Limit of natural Soil- 74.5%

Table 7.1:- Liquid limit for Fly Ash

Fly Ash	5%	10%	15%	20%
Water Content percentage	79.2	85.9	87.6	89.2

Table 7.2:- Liquid limit for Steel Slag

Steel Slag	5%	10%	15%	20%
Water Content Percentage	75.1	76.9	77.3	78.9

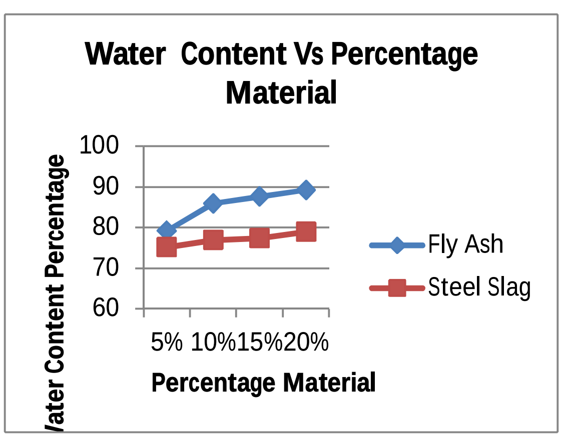

Fig 5- Graph representing Water content Vs Percentage material for Liquid Limit

As % of fly ash increase in soil mix than liquid limit increase in soil mix as compare with natural soil. As % of steel slag increase in soil mix than no significant decrease in liquid limit on compare to natural soil.

D. Plastic Limit

This test is conducted on natural soil and by mixing fly ash & steel slag in four proportions separately.

Plastic Limit of natural Soil- 35%

Table 8:- Plastic limit for Fly Ash

Fly Ash	5%	10%	15%	20%
Water Content Percentage	36.01	38.78	39.87	42.5

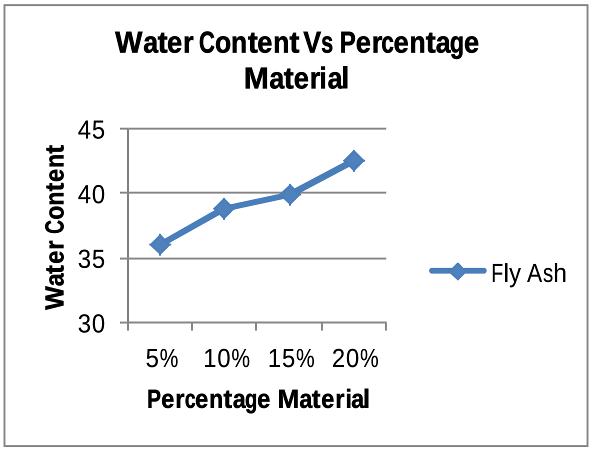

Fig 6- Graph representing Water content Vs Percentage material for Plastic Limit

Plastic Limit Determination for steel slag is not performing because it is difficult, due to pointed nature of steel slag.

As % of fly ash increase in soil mix then increase in plastic limit.

E. Compaction Test

This test is conducted on natural soil and by mixing fly ash & steel slag in four proportions separately.

Table 9- Compaction Test for Natural soil

Sr. No	Bulk Density	Dry Density	Water content %
1	1.13	1.25	10
2	1.60	1.40	14
3	1.84	1.56	18.57
4	1.74	1.45	20
5	1.73	1.39	25

Optimum Water Content- 18.57%

Maximum Dry Density- 1.56 gm/cc

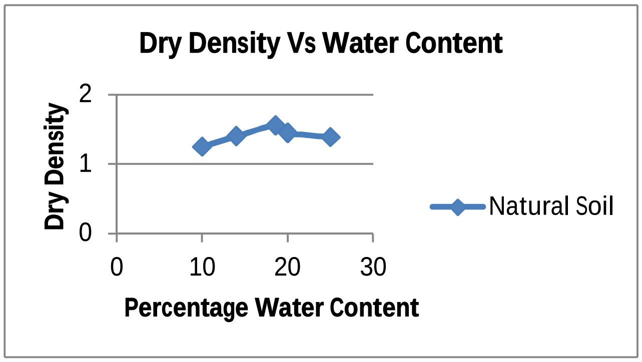

Fig 7- Graph representing Dry density Vs Percentage Water content for natural soil

1) *Compaction Test by Adding Fly Ash (5%):*

Table 10- Compaction Test for Fly Ash (5 %)

Sr. No	Bulk Density	Dry Density	Water %
1	1.42	1.22	16.8
2	1.524	1.27	20.3
3	1.6	1.3	23.76
4	1.56	1.25	25.6
5	1.53	1.20	28.7

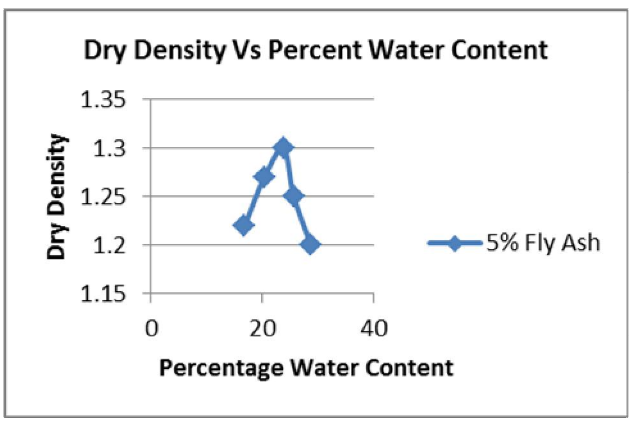

Fig 8- Graph representing Dry density Vs Percent Water Content for 5 % fly ash

2) *Compaction Test by Adding Fly Ash (10%):*

Table 11- Compaction test for Fly Ash (10 %)

Sr. No	Bulk Density	Dry Density	percentage Water content
1	1.4	1.12	25
2	1.42	1.21	27.32
3	1.62	1.23	32.28
4	1.60	1.19	35.06
5	1.54	1.13	37.38

Optimum Water Content- 32.8%
Maximum Dry Density- 1.23gm/cc

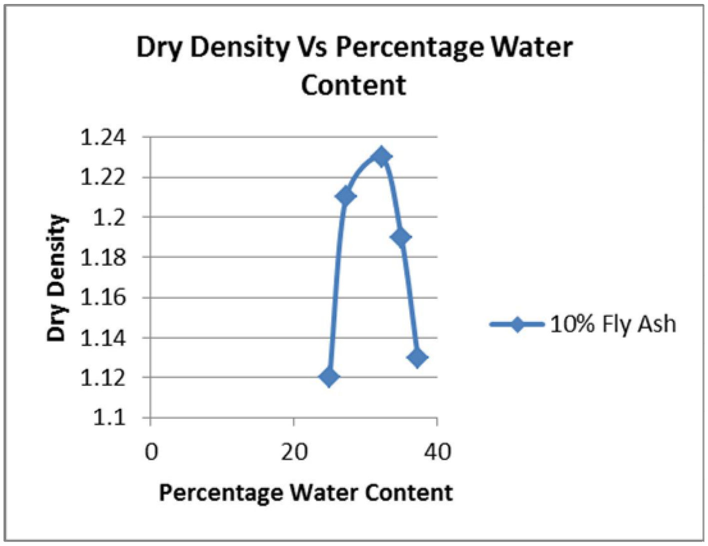

Fig 9- Graph representing Dry density Vs Percent Water Content for 10 % fly ash

3) Compaction Test by Adding Fly Ash (15%):

Table 12- Compaction test for Fly Ash (15 %)

Sr. No	Bulk Density	Dry Density	%age Water content
1	1.38	1.11	25.37
2	1.47	1.149	28.48
3	1.66	1.18	33.34
4	1.56	1.16	35.68
5	1.52	1.1	39.46

Optimum Water Content- 33.34%
Maximum Dry Density- 1.18 gm/cc

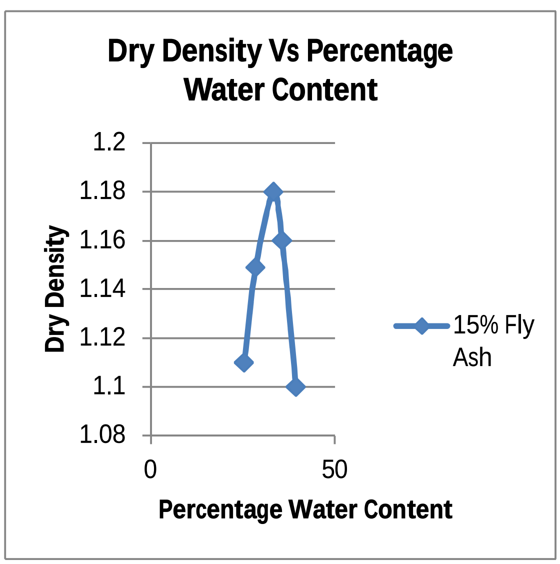

Fig 10- Graph representing Dry density VsPercent Water Content for 15 % fly ash

4) Compaction Test by Adding Fly Ash (20%):

Table 13- Compaction test for Fly Ash (20 %)

Sr. No	Bulk Density	Dry Density	%age Water Content
1	1.35	1.03	32.35
2	1.51	1.09	35.76
3	1.72	1.11	37.36
4	1.49	1.076	39.99
5	1.49	1.05	42.31

Optimum Water Content- 37.36%
Maximum Dry Density- 1.11 gm/cc

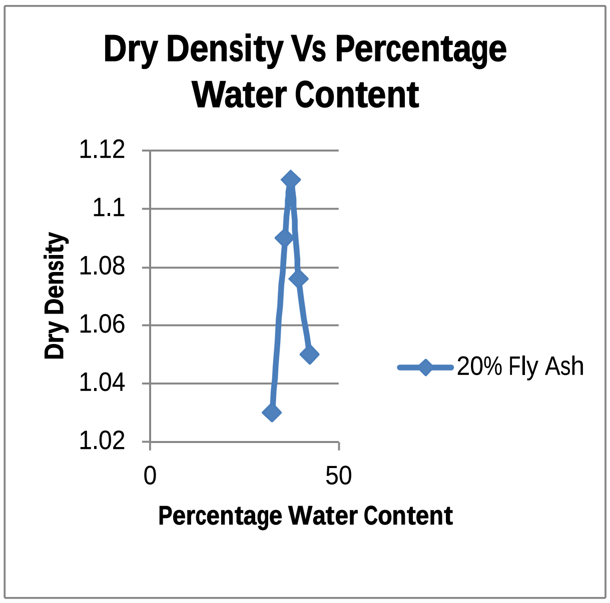

Fig 11-Graph representing Dry density Vs Percent Water Content for 20 % fly ash

5) Compaction Test by Adding Steel Slag (5%):

Table 14- Compaction Test for Steel Slag (5 %)

Sr. No	Bulk Density	Dry Density	%age Water Content
1	1.25	1.12	12.6
2	1.33	1.16	15.3
3	2.14	1.82	18.3
4	1.39	1.15	21.6
5	1.47	1.13	24.6

Optimum Water Content- 18.3%
Maximum Dry Density- 1.82 gm/cc

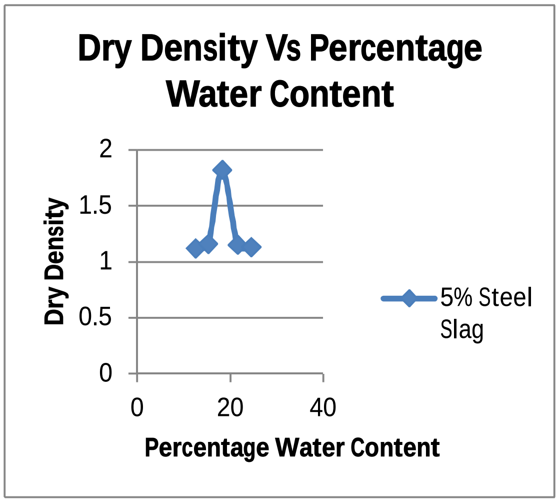

Fig 12- Graph representing Dry density Vs Percentage Water Content for 5% steel slag

6) Compaction Test by Adding Steel Slag (10%):

Table 15- Compaction Test for Steel Slag (10 %)

Sr. No	Bulk Density	Dry Density	percentage water content
1	2.04	1.83	12.68
2	2.25	1.96	15.32
3	2.44	2.09	17.5
4	2.22	1.87	19.36
5	2.18	1.79	22.45

Optimum Water Content- 17.5%
Maximum Dry Density- 2.09 gm/cc

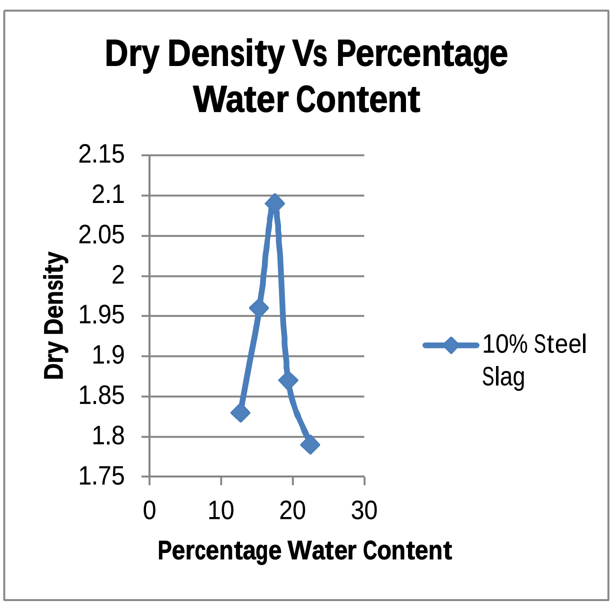

Fig 13- Graph representing Dry density Vs Percentage Water Content for 10% steel slag

7) Compaction Test by Adding Steel Slag (15%):

Table 16- Compaction Test for Steel Slag (15 %)

Sr. No	Bulk Density	Dry Density	%age water content
1	1.97	1.78	11.73
2	2.33	2.05	14.58
3	2.73	2.36	16.28
4	2.54	2.16	18.39
5	2.19	1.83	20.39

Optimum Water Content- 16.28%
Maximum Dry Density- 2.36 gm/cc

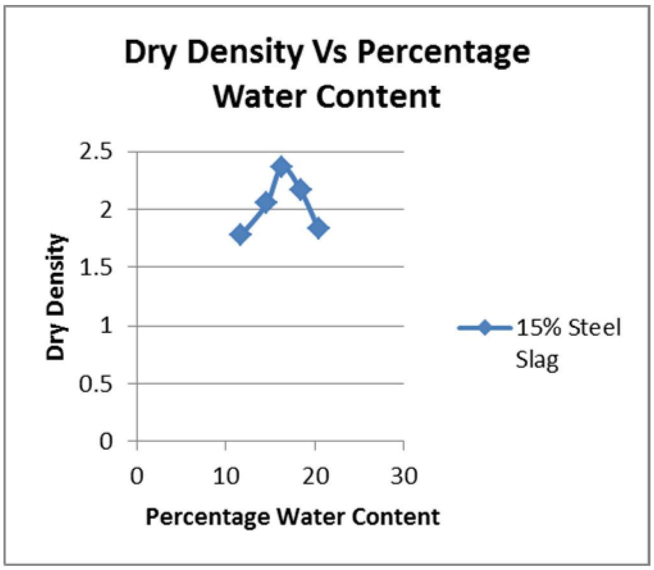

Fig 14-Graph representing Dry density Vs Percentage Water Content for 15% steel slag

8) Compaction Test by Adding Steel Slag (20%):

Table 17- Compaction Test for Steel Slag (20 %)

Sr. No	Bulk Density	Dry Density	% water conent
1	2.5	2.28	10.58
2	2.74	2.45	12.36
3	3.02	2.63	15.82
4	2.77	2.37	17.38
5	2.58	2.15	20.49

Optimum Water Content- 15.82%
Maximum Dry Density- 2.63 gm/cc

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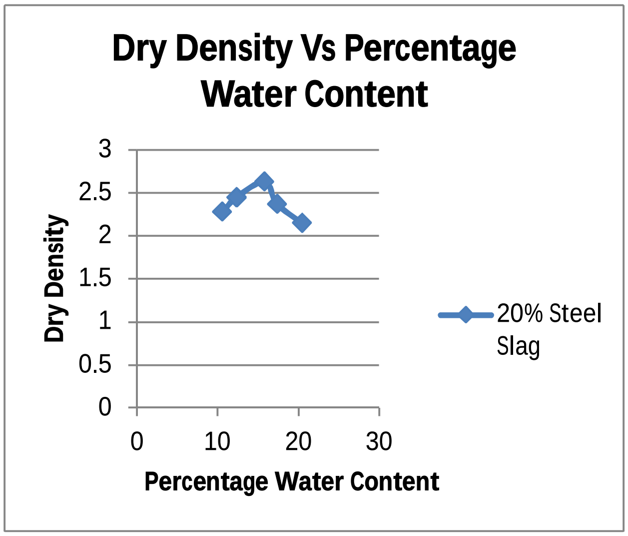

Fig 15- Graph representing Dry density Vs Percentage Water Content for 20% steel slag

Table 17- Final Observations at various proportions of Fly Ash

Fly Ash	5%	10%	15%	20%
Optimum Water content	23.76	32.28	33.34	37.33
Maximum Dry Density	1.30	1.23	1.18	1.11

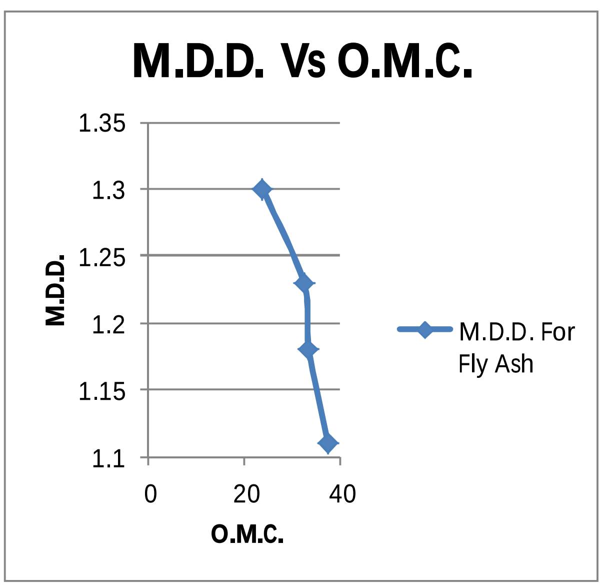

Fig 16- Graph representing M.D.D. Vs O.M.C. for fly ash

As we go on increasing % of fly ash to natural soil then there is significant decrease in MDD & increase in OMC

Table 18- Final Observations at various proportions of Steel Slag

Steel slag	5%	10%	15%	20%
Optimum Water content	18.3	17.5	16.2	15.8
Maximum Dry Density	1.82	2.09	2.36	2.63

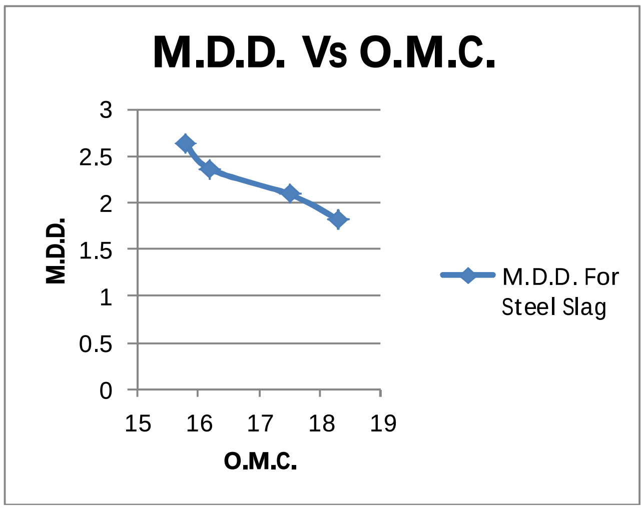

Fig 17-Graph representing M.D.D. Vs O.M.C. for steel slag

As we goes on increasing % of Steel slag to the natural soil then there is increase in MDD & decrease in OMC.

F. Free Swell

This test is conducted on natural soil and by mixing fly ash & steel slag in four Proportions separately, % increase in volume of natural soil – 53.33%

Table 19.1- Free swell test using Fly Ash and Steel Slag

Fly ash	5%	10%	15%	20%
Percentage increase in volume	47.5	42.3	40.2	36.8

Table 19.2- Free swell test using Fly Ash and Steel Slag

Steel slag	5%	10%	15%	20%
Percentage increase in volume	53	52.68	50.67	49.83

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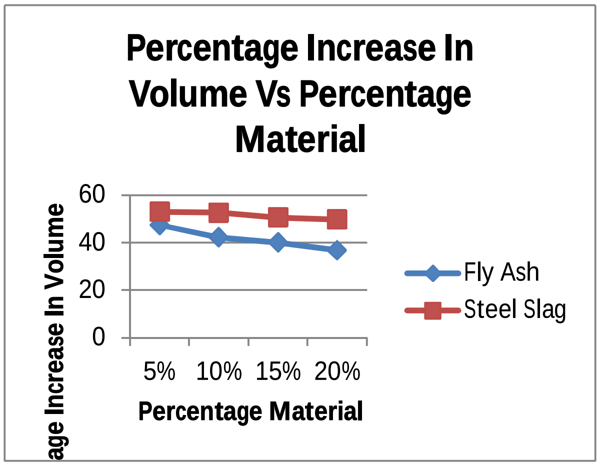

Fig 18- Graph representing Percentage increase in volume Vs Percentage material

The swelling of soil is affected by adding fly ash & steel slag. The swelling of soil is decreased by adding fly ash, as it absorbs the water in the soil. And by adding the steel slag the swelling property of soil is not affected as the steel slag does not absorbs the water.

G. California Bearing Ratio Test

This test is conducted on natural soil and by mixing fly ash & steel slag in four proportions separately.

California bearing ratio of natural Soil- 425kg at 2.5mm (std. 1370kg) = 8.93%

Table 20.1- California bearing ratio test using Fly Ash

Fly Ash	5%	10%	15%	20%
CBR	9.2	12	17.45	22.9

Table 20.2-California bearing ratio test using Steel Slag

Steel Slag	5%	10%	15%	20%
CBR	12.13	16.1	22.5	30.3

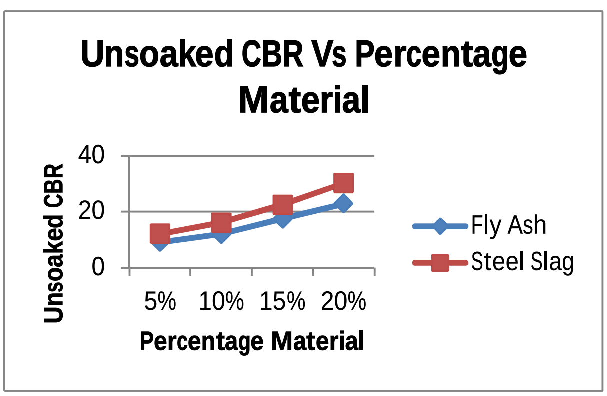

Fig 19- Graph representing Unsoaked CBR Vs Percentage Material

CBR value increase in both the cases as we increase % in both the cases as compared to natural soil.

VI. COSTING

A. Cost for Piling

Pile diameter-500mm
Area-$\pi/4 X 500^2=0.196m^2$
Depth of piling=10m
Total volume= $1.96m^3$
Pile excavation= $1.96m^3$ X 175(rmt) =343Rs
Hard rock drilling- 1 meter
=0.196 X 1
= $0.196m^3$
0.196 X 1050 = Rs 205/-
Total excavation cost= 343+205=Rs 548/-
Concreting volume- 0.196 X 11m= $2.15m^3$
Concreting- 1865rmt X 11m = 20515
Steel-
2% of concrete = 2% X 2.156 = 0.04
0.04 X 7850 = 314 Kg
Steel cost- 314 X 40rs = Rs 12560/-
Total cost of pile= 548+20515+12560
=Rs 33623/-
Approximately 30000Rs/pile
Total cost of piling= 30000 X 150 nos.
=Rs 4500000/-

B. Cost for Cement Stabilization

Plot area= 4 acres X 40000 sqft
= 160000 sqft
= $16000m^2$
Stabilization depth= 4 meters
=16000 X 4
= $64000m^3$
10% of total cement is added
10 % of 64000 = $6400m^3$
$1m^3$=33 bags
6400 X 33 = 211200 bags
Total cost of stabilizing = 211200 X 300
=Rs 63360000/-

VII. CONCLUSION

A. It is observed that if we add fly ash in natural soil then decrease in water content by2.91%, 4.91%, 9%, 12.04% for 5%, 10%, 15%, 20% of fly ash (Refer table no). But no effect of steel slag on water content & liquid limit & plastic limit.
B. It is observed that Atterberg's limit that is liquid limit increases by 4.7%, 11.4%, 13.1%, 14.7% for 5%, 10%, 15%, 20% of fly ash (Refer table no) & plastic limit also increases by 1.01%, 3.78%, 4.87%, 7.5% for 5%, 10%, 15%, 20% of fly ash (Refer table)as compared to natural soil.
C. It is observed that Atterberg's limit that is liquid limit increases with 0.4%, 2.4%, 2.8%, 4.4% for 5%, 10%, 15%, 20% of steel slag as compared to natural soil.
D. In compaction test it is observed as the percentage of fly ash is increased to natural soil MDD is decreased.
E. As percentage of fly ash is increased the density is decreased so it is advisable to mix the fly ash up to 5 to 10percent.

F. From CBR test it is observed that addition of fly ash CBR ratio increases with 0.27%, 3.07%, 8.52%, 13.97% for 5%, 10%, 15%, 20% for fly ash (refer table no)and steel slag there is increased in CBR value 3.2%, 7.17%, 13.57%, 21.37% for 5%, 10%, 15%, 20%as compared to natural soil.

G. Thus taking into consideration the cost, pile foundation is preferable.

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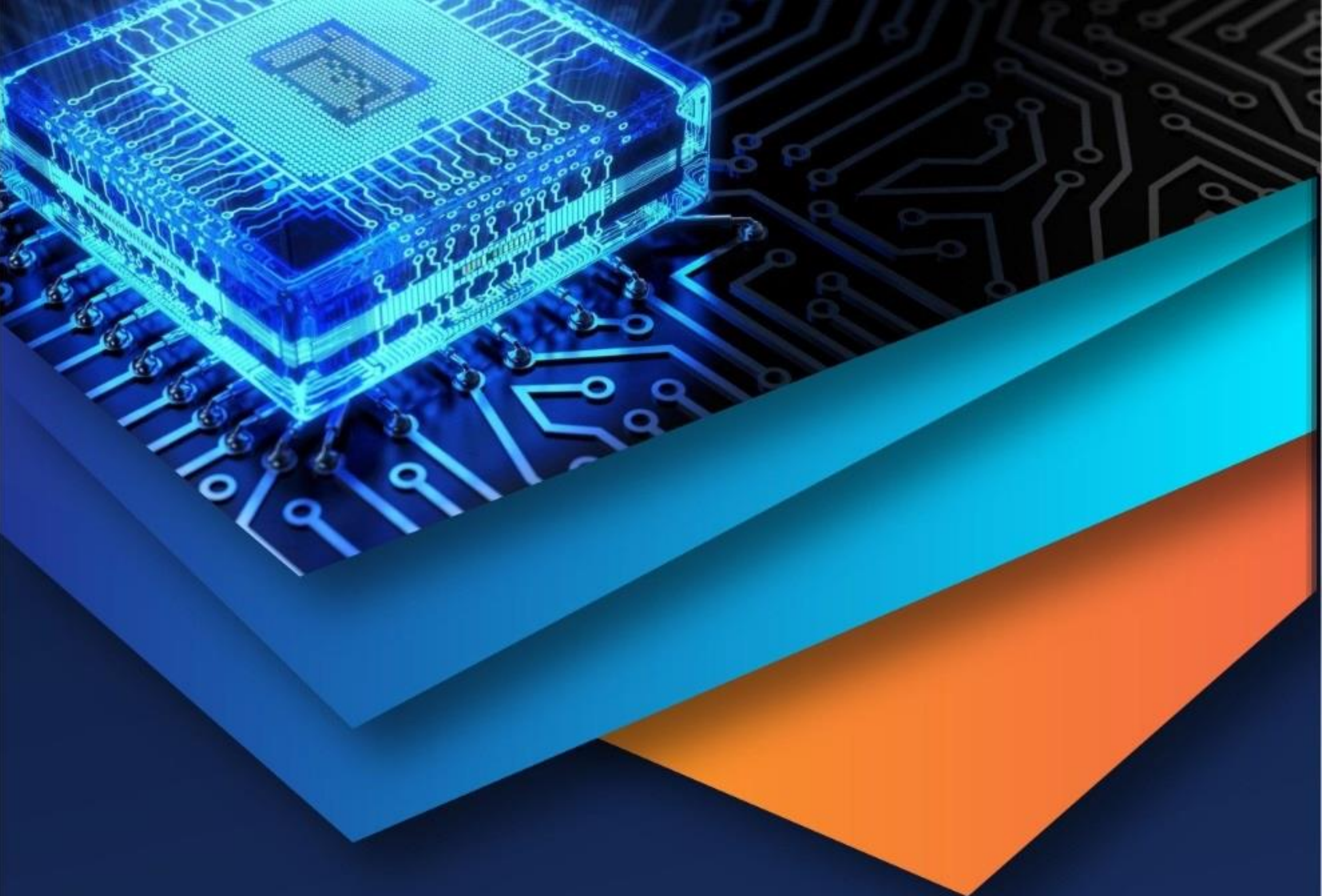

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