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A Laboratory Study on the Performance of Mill Scale Dust on Improving the Properties of the Marine Clay as Subgrade for Flexible Pavements

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Abstract: Globally, the Marine Clay is found in coastal areas. It is a problematic soil due to its varying moisture content and compressibility characteristics. In marine clays, the swelling and shrinkage behaviour is due to the clay mineral montmorillonite. Hence the constructions on the Marine Clay have become a challenging task for civil engineers. The Pavements on marine soils have low strength and highly compressible, resulting in poor performance and increased maintenance costs. Soil stabilization helps a lot in improving the strength characteristics of marine soil. Mill scale dust is a by-product from lathe machine workshops, which contains ferrous (Fe) predominantly, supports in improving the strength characteristics. In this investigation, the efficacy of mill scale dust has been studied for improving the strength parameters of the Marine Clay to suit it as subgrade for flexible pavements under cyclic pressures. In view of the recent developments in the coastal area, a great number of ports and industries are being created. The availability of land for the development of commercial, housing, industries and infrastructure etc., is limited. The scarcity of land become big task for civil engineers in civil engineering application and also become a challenged task for constructions of various structures in problematic soils. The Marine Clay is a kind of micro crystalline clay. It comprises clay minerals such as chlorite, illite, kaolinite, and montmorillonite, as well as non clay minerals such as quartz and feldspar. Because of the unpredictability associated with the performance of the Marine Clay, it provides significant challenges in pavement and foundation construction.

Due to its poor technical qualities, employing the Marine Clay (locally accessible soils) as a sub grade in a coastal zone will not give appropriate results. Several corrective measures, such as soil replacement, will be implemented, in which weak soil particles will be removed and replaced with rich soil particles. However, this is not economically possible, because it raises the project's budget. So, to avoid this problem and to improve soft soils, there are several solutions available, one of which is soil stabilization using admixtures (industrial by-products) and certain chemical additions. In the present study an attempt has been taken to improve the properties of Marine Clay with the percentage variation of Mill Scale Dust. The Marine Clay exhibited suitable on addition of 25 % Mill Scale Dust as optimum. The treated Marine Clay as exhibited suitable CBR value as per codes of practice [IRC 37:2012] and this treated Marine Clay can be used as subgrade for flexible pavements. The cyclic plate load test were conducted on treated and untreated Marine Clay model flexible pavements in the laboratory. It is observed from the laboratory test results that the treated Marine Clay is more effective as subgrade for flexible pavements under cyclic pressures.

Keywords: The Marine Clay, Mill Scale Dust, Subgrade, Stabilization, Flexible Pavements.

I. INTRODUCTION

Engineers have been essential to build earth constructions such as embankments and major highways over the Marine Clay deposits with inadequate bearing capacities and excessive settlement characteristics due to rapid development methods and related urbanization in certain parts of India. Construction on the Marine Clay deposits has proven difficult because of the high natural moisture content. Low permeability and high compressibility characterize this clay soil.

The Marine Clay is a kind of soil that can be found both on the ocean floor and on the coast. India, as a peninsular country, has a wide coastal region with a length of 7,517 kilometers. West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, and some portions of Gujarat are home to the Marine Clay.

These soils are often had low density, poor shear strength, and are very compressible in nature. The characteristics of saturated Marine Clay differ markedly from those of damp and dry soil. The Marine Clay is microcrystalline in nature, and it contains clay minerals such as chlorite, kaolinite, and illite, as well as non-clay minerals such as quartz and feldspar. The soils include a higher percentage of organic matter, which works as a cementing agent. Because of the unpredictability associated with their performance, the Marine Clay, in particular, can cause significant challenges in pavement design. They are frequently unstable beneath the pavement and are prone to a variety of difficulties with minor variations in moisture content. These soils are often compacted, very saturated, soft, and sensitive. These are often of low density, poor shear strength, and expansive in character. When wet, the Marine Clays expand and become soft, but when dry, they shrink and become hard.

The Marine Clays expand when they come into contact with moisture and shrink when that moisture is removed. These volume variations in swelling soils generate a slew of issues in structures that come into touch with them or are built on top of them. The liquid limit values of the Marine Clays in India range from 50 to 100 percent, the plasticity index ranges from 20 to 65 percent, and the shrinkage limit is from 9 to 14 percent.

A considerable literature has determined the severity and amount of damage produced by swelling soil deposits on various constructions across the world. The loss caused by damaged buildings demonstrated the necessity for more reliable analysis of such soil, as well as the essential ways to eliminate or limit the effect of soil volume change.

When blended in the right quantities with problematic soils, additives such as lime, fly ash, Portland cement, saw dust, and, more recently, synthetics can improve these issues. These extracts can be used alone or in blend, and each has creation difficulties that affect their performance.

II. MATERIALS AND METHODOLOGY

A. Materials

1) Marine Clay

The Marine Clay was collected at a depth of 0.3m-1.0m from Kakinada Sea Ports Limited in Kakinada. The port of Kakinada is located on India's east coast. Changes in the stress system, moisture content, and pore fluid chemistry are all very sensitive to soft the Marine Clays. Geotechnical engineers believe that any of the existing ground improvement techniques must be used to improve the behaviour of these deposits.

2) Mill Scale Dust

Mill Scale Dust is a by-product in lath Machine during smoothening of rusted cast iron. The flaky surface of hot rolled steel that consists of the mixed iron oxides iron (II) oxide (FeO), iron (III) oxide (Fe_2O_3), and iron (II,III) oxide (Fe_2O_3) is known as mill scale (Fe_3O_4, magnetite).

When red hot iron or steel billets are rolled in rolling mills, mill scale accumulates on the exterior surfaces of plates, sheets, and profiles. Mill scale has a bluish-black appearance. It is typically less than 0.1 mm (0.0039 in) thick and initially clings to the steel surface, protecting it from air corrosion if there is no break in the coating.

Because it is electro chemically cathodic to steel, any break in the mill scale coating will result in rapid corrosion of the steel exposed at the crack. Mill scale is therefore a benefit for a time until its coating cracks owing to handling of the steel product or any other mechanical reason.

When the steel needs to be treated, mill scale becomes an annoyance. Any paint that is placed over it is useless because it will be washed away with the scale when moisture-laden air passes beneath it. Thus, mill scale can be removed from steel surfaces by flame cleaning, pickling, or abrasive blasting, all of which are time-consuming and energy-intensive processes. This is why shipbuilders and steel fixers used to leave freshly rolled steel and rebar brought from mills out in the open to 'weather' until much of the scale came off due to atmospheric action. Nowadays, most steel mills can offer their product with mill scale removed and steel coated with shop primers, allowing for safe welding or painting. Mill scale produced in rolling mills will be collected and recycled at a sinter plant.

For this investigation, Mill Scale Dust was collected from the Jaggampeta East Godavari district of Andhra Pradesh, India.

B. Methodology

The Marine Clay is treated with various percentages of Mill Scale Dust to test the suitability of mix proportion as subgrade of the flexible pavement as given in the below table.

TABLE 1
METHODOLOGY

Sl No	Trail Mix	Marine Clay (%)	Mill Scale Dust (%)
1	Trail Mix 1	100	0
2	Trail Mix 2	85	15
3	Trail Mix 3	80	20
4	Trail Mix 4	75	25

III. LABORATORY EXPERIMENTS

A series of laboratory tests were conducted on natural soil and stabilized mixes to evaluate improvements in engineering behavior, with all procedures performed in accordance with Indian Standard (IS) code regulations. The soil's expansiveness was first determined via the Differential Free Swell (DFS) test (IS 2720 – Part 40) using distilled water and kerosene, where the reduction in DFS values for treated samples helped assess the effectiveness of stabilization in controlling swelling. The specific gravity of the soil solids was measured using a pycnometer (IS 2720 – Part 3) to provide insight into mineralogical composition and support compaction and classification studies. To evaluate workability and swelling potential, the liquid limit, plastic limit, and plasticity index were determined for both untreated and treated soils following IS 2720 – Part 5. Compaction characteristics, specifically the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), were obtained via the Standard Proctor compaction test (IS 2720 – Part 7) to study the influence of Mill Scale Dust combinations. Finally, soaked and unsoaked California Bearing Ratio (CBR) values (IS 2720 – Part 16) were determined to evaluate the potential use of the stabilized soil in pavement subgrades.

IV. RESULTS AND DISCUSSIONS

A. *Untreated Marine Clay*

The properties of the untreated Marine Clay are given in the table below.

TABLE 2
PROPERTIES OF UNTREATED MARINE CLAY

S. No	**Property**	**Symbol**	**Untreated The Marine Clay**
1.	Differential Free Swell (%)		40
2.	Specific Gravity	G	2.57
3.	Liquid Limit (%)	WL	79.2
4.	Plastic Limit (%)	WP	30.4
5.	Plasticity Index (%)	IP	48.8
6.	Soil Classification	-	CH
7.	Maximum Dry Density(g/cc)	MDD	1.601
8.	Optimum Moisture Content (%)	OMC	19.54
9.	CBR (%)		1.344

B. *Differential Free Swell*

TABLE 3
VARIATION OF DFS VALUES OF THE MARINE CLAY BLENDED WITH DIFFERENT PERCENTAGES OF MILL SCALE DUST

S.no	**MIX PROPORTIONS**	**DFS (%)**
1.	M.C+0% MSD	40
2.	M.C+15% MSD	35
3.	M.C+20% MSD	30
4.	M.C+25% MSD	25

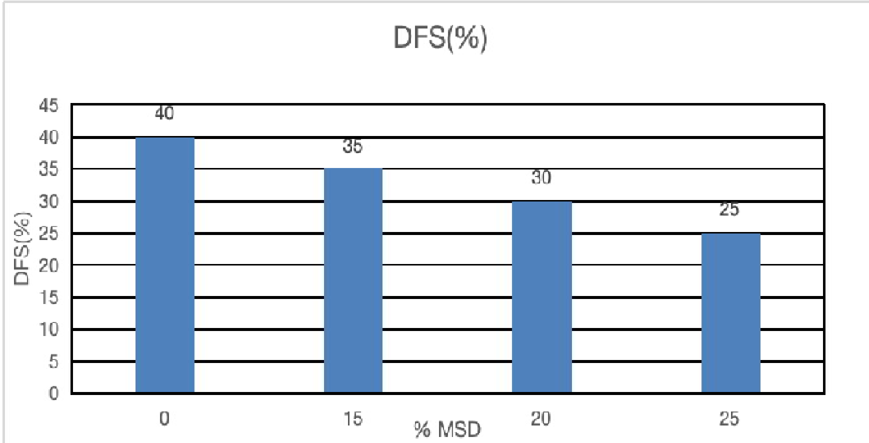

Fig 1 Variation of DFS of the Marine Clay blended with Different percentages of Mill Scale Dust

C. Atterberg Limits

TABLE 4
VARIATION OF LL, PL AND PI OF THE MARINE CLAY BLENDED WITH DIFFERENT PERCENTAGES OF MILL SCALE DUST

S.no	MIX PROPORTIONS	LL (%)	PL (%)	PI (%)
1.	M.C+0% MSD	57.09	25.62	31.47
2.	M.C+15% MSD	51.23	27.83	23.4
3.	M.C+20% MSD	47.93	29.27	18.66
4.	M.C+25% MSD	42.79	30.59	12.2

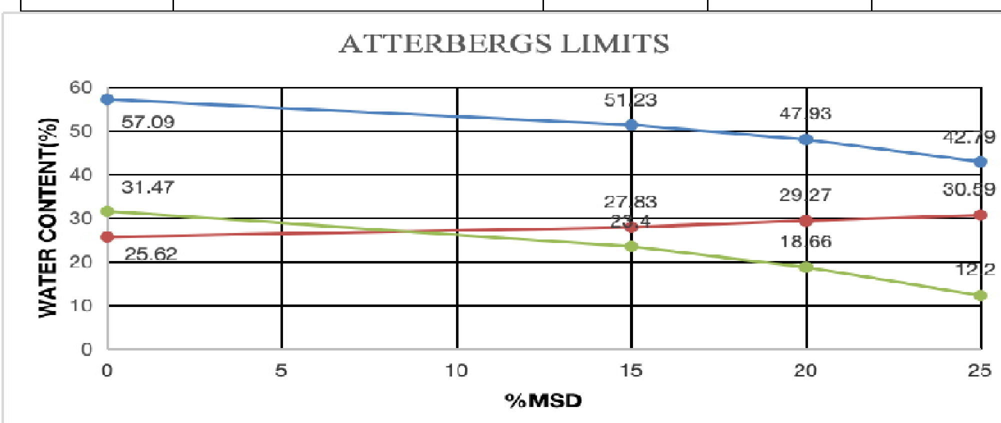

Fig 2 Variation of LL, PL and PI of The Marine Clay blended with Different Percentages of Mill Scale Dust

D. Compaction Characteristics

1) Maximum Dry Density

TABLE 5
VARIATION OF MDD FOR THE MARINE CLAY TREATED WITH DIFFERENT PERCENTAGES OF MILL SCALE DUST

S.no	MIX PROPORTIONS	MDD(g/cc)
1.	M.C+0% MSD	1.601
2.	M.C+15% MSD	1.712
3.	M.C+20% MSD	1.879
4.	M.C+25% MSD	1.986

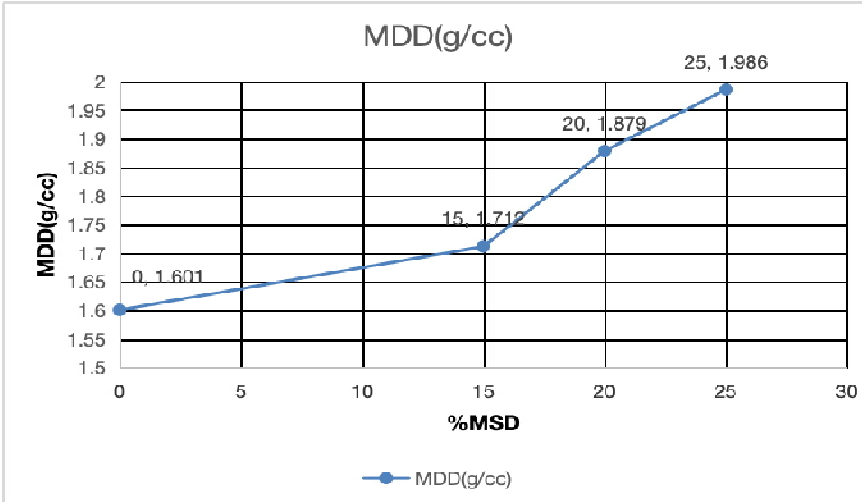

Fig 3 Variation of MDD for The Marine Clay Treated with Different Percentages of Mill Scale Dust

2) Optimum Moisture Content

TABLE 6

VARIATION OF OMC FOR THE MARINE CLAY TREATED WITH DIFFERENT PERCENTAGES OF MILL SCALE DUST

S.no	MIX PROPORTIONS	OMC (%)
1.	M.C+0% MSD	19.54
2.	M.C+15% MSD	15.59
3.	M.C+20% MSD	14.96
4.	M.C+25% MSD	13.012

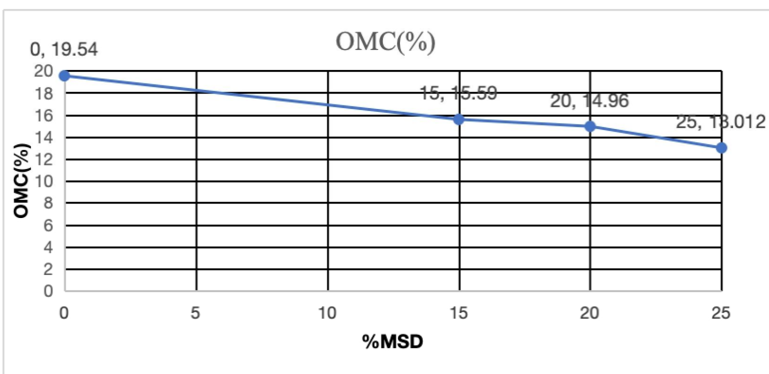

Fig 4 Variation of OMC for The Marine Clay Treated with Different Percentages of Mill Scale Dust

E. California Bearing Ratio

TABLE 7

VARIATION OF CBR VALUES FOR THE MARINE CLAY WITH DIFFERENT PERCENTAGES OF MILL SCALE DUST

S.no	MIX PROPORTIONS	CBR (%)
1.	M.C+0% MSD	1.344
2.	M.C+15% MSD	6.722
3.	M.C+20% MSD	7.618
4.	M.C+25% MSD	8.963

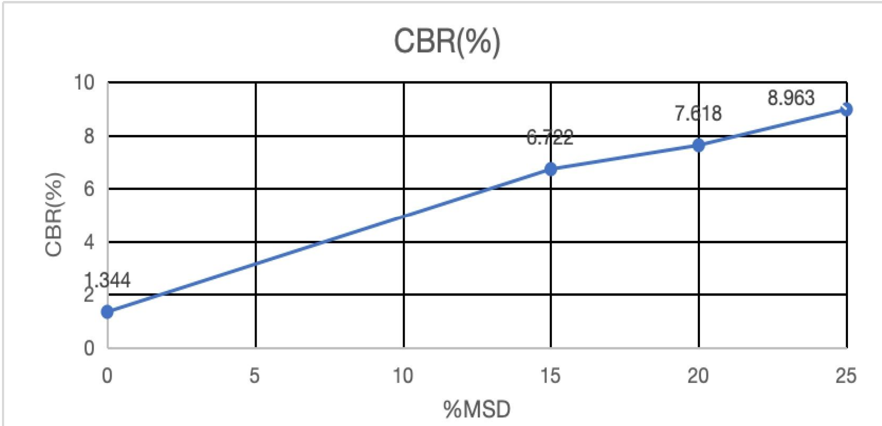

Fig 5 Variation of CBR values for the Marine Clay with Different Percentages of Mill Scale Dusts

F. Discussion

It was observed from the laboratory test results that the Marine Clay treated with an optimum of 25 % of Mill Scale Dust, has exhibited the CBR value is 8.96%. As per codes of practice IRC 37:2012 the CBR value of subgrade for flexible pavements is greater than or equal to 8%.

V. CONCLUSIONS

1) It is noticed from the laboratory test results the Differential Free Swell of Marine Clay has been improved by 37.5 % when compared with untreated Marine Clay.
2) It is noticed from the laboratory test results the liquid limit of Marine Clay has been decreased by 85.04 % when compared with untreated Marine Clay.
3) It is also observed from laboratory test results that the plasticity index of the treated Marine Clay has been enhanced by 75.03 % on addition of 25% Mill Scale Dust.
4) It is noticed from the laboratory test results the O.M.C of Marine Clay has been improved by 33.41 % when compared with untreated Marine Clay.
5) It is noticed from the laboratory test results the M.D.D of Marine Clay has been improved by 41.75 % when compared with untreated Marine Clay.
6) It is noticed from the laboratory test results the C.B.R of Marine Clay has been improved by 8.96 % when compared with untreated Marine Clay.

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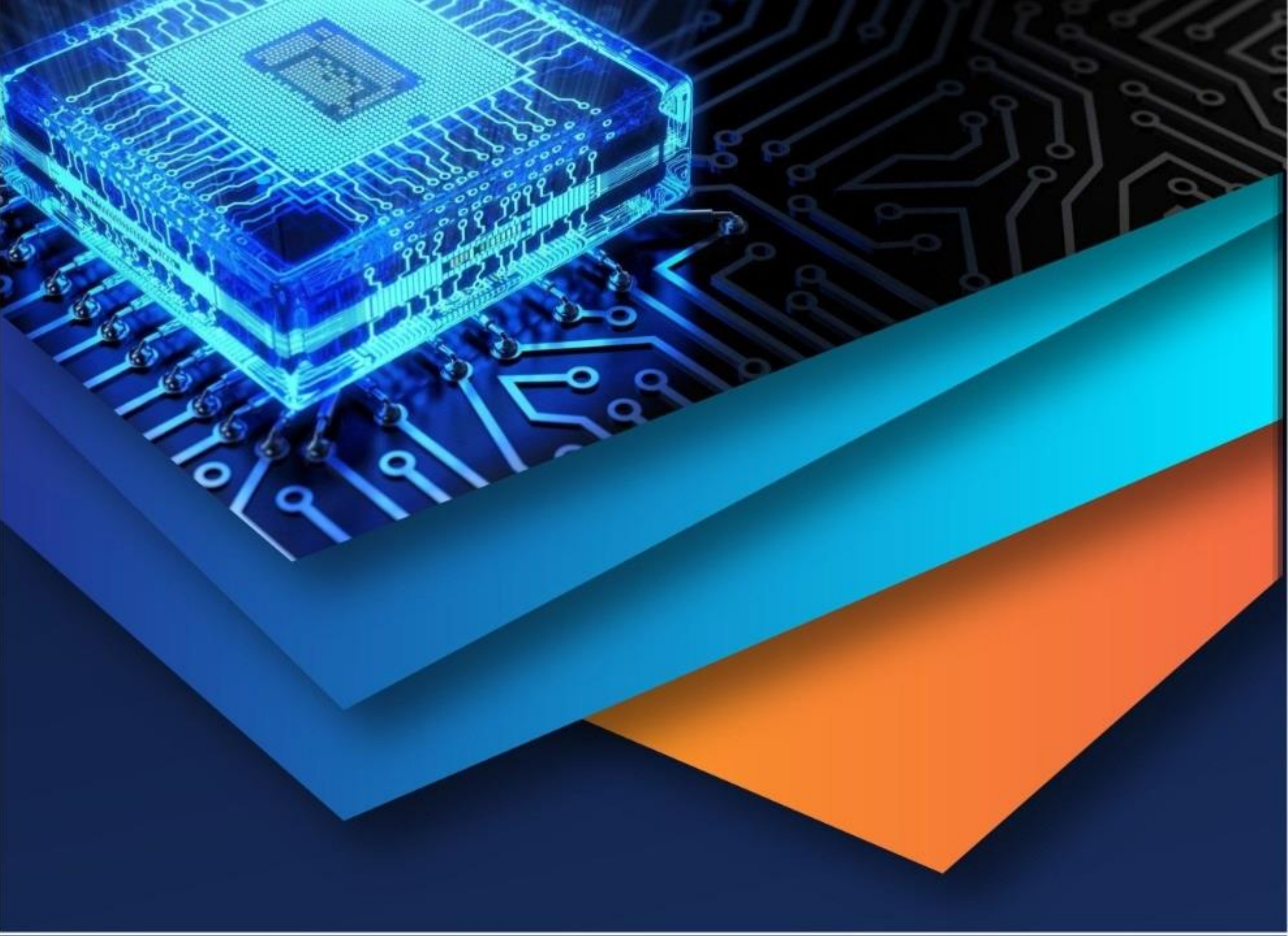

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