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Determination of Marshall Stability value for BC Grade-II Bituminous Mix by Replacing Twenty mm Down Size Aggregates with Waste Plastic Material

Naveena N[1]
[1]*Assistant Professor, Department of Civil Engineering, B.T.L.I.T, Bengaluru*

***Abstract:** The main objective of this project is use of waste plastic material in the flexible pavement construction and analyse the Marshall Stability value for the bituminous mix in the laboratory. Since the traffic intensity is increasing every year, because of which there will be more repetition of loaded vehicles. There is a need for better quality of pavement in terms of strength, durability and resistance to the deformation for avoiding deterioration of pavement and obtain better raiding quality. This study will take care of aspects like better pavement characteristics and eco-friendly nature in terms of reusing the waste materials. In the present study twenty mm down aggregates is replaced for about five percent with plastic waste consisting LDPE (low density polyethylene) or HDPE (high density polyethylene) and BC grade-II mix is prepared. This can be used for surface course of flexible pavement in road construction. The Marshall Stability values are checked for the above samples and is compared with the conventional BC grade-II mix. By using above plastic waste materials there will be increase the strength, durability, resistance to the deformation and water resistance as well as providing a mean to dispose of wastes. At the end, it concludes that the modified bituminous mix is cheaper than conventional bituminous mix. The test result of modified bituminous mix is found to be better than conventional bituminous mix.*
***Keywords:** Marshall Stability, bituminous mix, waste plastic material, BC Grade-II*

I. INTRODUCTION

A material that contains one or more organic polymers of large molecular weight, solid in its finished state and at some state while manufacturing or processing into finished articles, can be shaped by its flow, is called as 'Plastic'. Plastics can be divided in to two major categories: thermoses and thermoplastics. A thermoset solidifies or sets irreversibly when heated. They are useful for their durability and strength, and are therefore used primarily in automobiles and construction applications. A thermoplastic softens when exposed to heat and returns to original condition at room temperature. Thermoplastics can easily be shaped and moulded into products such as milk jugs, floor coverings, credit cards, and carpet fibres. With increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. Plastic in different forms is found to be almost 5% in municipal solid waste, which is toxic in nature. Due to its biodegradability it creates stagnation of water and associated hygiene problems. In order to mitigate this problem experiments have been carried out whether this waste plastic can be reused productively. The experimentation at several institutes indicated that the waste plastic, when added to hot aggregate will form a fine coat of plastic over the aggregate and such aggregate, when mixed with the binder is found to give higher strength, higher resistance to water and better performance over a period of time. Waste plastic such as carry bags, disposable cups and laminated pouches like chips, pan masala, aluminium foil and packaging material used for biscuits, chocolate, milk and grocery items can be used for surfacing roads. Use of plastic in road construction not only increases its durability but also makes it economically sound and environment friendly. In the present study plastic waste is used by replacing the twenty mm down size aggregates and Marshall Stability value for the bituminous mix is checked. The roads that are constructed using plastic waste are known as Plastic Roads and are found to perform better compared to those constructed with conventional bitumen. The steady increase in high traffic intensity in terms of commercial vehicles, the increase in over loading of trucks and the significant variation in daily and seasonal temperature demand improved road characteristics. Under these situations, it is essential to modify the asphalt cement using modifiers to improve its engineering properties. On the other hand, the environmental problem such as disposal of waste plastic is major concern. To overcome the problems the modifiers (waste plastic) are used. Among various types of modifiers, polymers are probably the most promising.

A. Objectives

Main motto is to efficiently utilize the waste plastic in constructive way so that it can be beneficial to society however main objectives of current project work are:

1) To utilize the plastic waste and to reduce its impact on environment.
2) To analyse the performance tests like Marshall Stability value for conventional BC Grade-II mix and compared with BC grade-II mix that is prepared by replacing 5% of waste plastic material.

II. LITERATURE REVIEW

Zoorab & Suparma reported the use of recycled plastics composed predominantly of polypropylene and low density polyethylene in plain bituminous concrete mixtures with increased durability and improved fatigue life. Dense bituminous macadam with recycled plastics, mainly low density polyethylene (LDPE) replacing 30% of 2.36–5mm aggregates, reduced the mix density by 16% and showed a 250% increase in Marshall Stability; the indirect tensile strength (ITS) was also improved in the 'Plastiphalt' mixtures. D.N. Little worked on the same theme and he found that resistance to deformation of asphaltic concrete modified with low density polythene was improved in comparison with unmodified mixes. It was found that the recycled polyethylene bags may be useful in bituminous pavements resulting in reduced permanent deformation in the form of rutting and reduced low temperature cracking of pavement surfacing Binduetal. The director of the Central Road Research Institute (CRRI) said that bitumen mixed with plastic or rubber improves the quality and life of roads. The deputy director of the CRRI said that polymers mixed with bitumen increased the construction cost up to six per cent, but increased the longevity of roads manifold. The performance studies carried out on the roads constructed in Tamil Nadu indicated satisfactory performance with good skid resistance, good texture value, stronger and less amount of progressive unevenness over a period of time. The experimentation carried out by CRRI also indicated better stability value, indicating higher strength, less flow and more air voids. Al-Hadidy A.I., Yi-qiu Tan (2009), "Effect of polyethylene on life of flexible pavements", Ms.Apurva Chavan (2013) says that using plastic waste in mix will help reduction in need of bitumen by around 10%, increase the strength and performance of road, avoid use of anti-stripping agent, avoid disposal of plastic waste by incineration and land filling and ultimately develop a technology, which is eco-friendly.

III. MATERIAL AND METHODOLOGY ADOPTED

Selection of mix constituents:
Binder and aggregates are the two main constituents of bituminous mix.
Binder: VG-30 grade bitumen is used in the present study.
Aggregate: Aggregate of 20mm down, 12.5mm down, Stone Dust and cement is used as Filler
Plastic material:

TABLE I: PROPERTIES OF LDPEP AND HDPEP

Types of plastic	Chemical formation	Density (gm/cm^3)	Softening point
Low Density poly-ethylene Plastic (LDPEP)	(-CH2-CH2-)n	0.9 to 0.95	100° c to 120°c
High Density poly-ethylene Plastic(HDPEP)	(-CH2-CH2-)n	0.95 to 0.96	120° c to 130°c

IV. RESULTS AND DISCUSSIONS

A. Tests on Aggregates

Table Ii: Observation & Tabulation Of Aggregate Impact Value Test And Los Angeles Abrasion Value Test

Sl. No.	Aggregate Impact Value				Los Angeles abrasion value			
	0 % Plastic	1 % Plastic	3 % Plastic	5 % Plastic	0 % Plastic	1 % Plastic	3 % Plastic	5 % Plastic
1	23.36 %	21.2 %	18.5 %	17 %	28.7%	28.3%	28 %	26 %

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Table Iii: Observation & Tabulation Of Water Absorption Test And Crushing Value Test

Sl. No.	Specific Gravity			Crushing Test		
	0 % Plastic	3 % Plastic	5 % Plastic	0 % Plastic	3 % Plastic	5 % Plastic
1	1.1 %	0.7 %	0.5 %	21.64 %	23.7 %	25.64 %

table iv: observation & tabulation of stripping value test for aggregates

Sl. No.	Uncovered area/stripping percentage		
	0 % Plastic	3 % Plastic	5 % Plastic
1	5 %	3 %	1 %

B. *Tests on Bitumen*

Table V: Consolidated Test Results Of Conventional Bitumen

Test	Result	Ranges
Ductility test	87.50 cm	Min 40 cm
Penetration value	67.50 mm	60-70 mm
Softening Point	46.45^{0}C	45-60 ˚C
Specific Gravity test	1.011	0.97 - 1.02

Proportioning of aggregates by rothfuth’s method:
Observation & Tabulation:
Material - A – 19 mm down size aggregates
Material - B – 12.50 mm down size aggregates
Material - C – 6.30 mm down size aggregates
Material - D – 4.75 mm down size aggregates

Table Vi: Proportioning Of Four Materials A, B, C & D To Be Mixed As Per Given Below For Bc Grade Ii

IS Sieve Size (mm)	% Passing Materials				Obtained gradation	Specified gradation BC – II
	A	B	C	D		
19.00	100	100	100	100	100	100
13.20	70.80	100	100	100	96.2	90-100
9.50	60.00	97	100	100	82.4	70-88
4.75	1.70	10	85	99.80	69.23	53-71
2.36	0.40	0.10	13	98.20	49.10	42-58
1.18	0.14	0.08	4.5	76.66	37.05	34-48
0.6	-	0.06	0.01	60.30	28.35	26-38
0.30	-	0.04	-	39.20	18.43	18-28
0.15	-	0.02	-	18.70	8.79	12-20
0.075	-	-	-	6.00	2.86	4-10

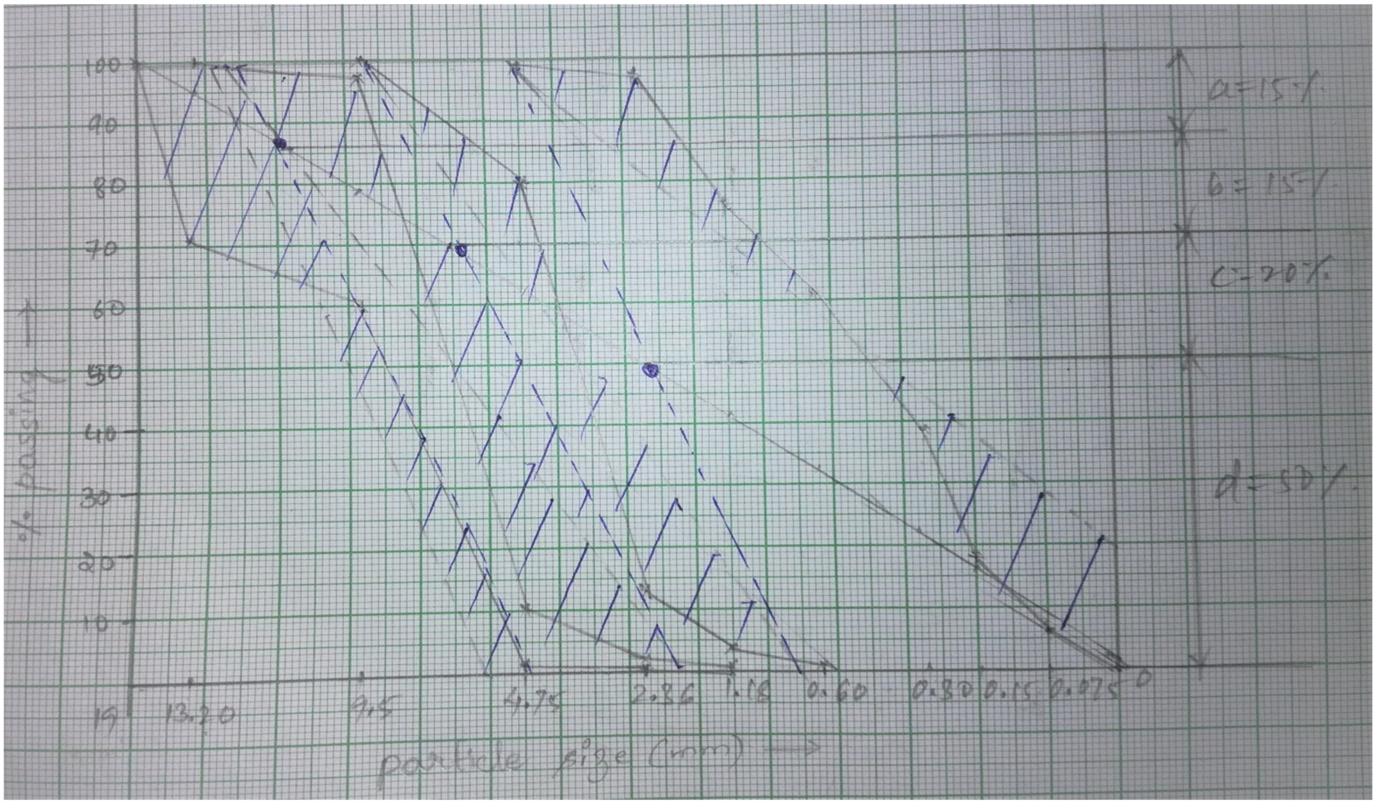

Fig. 1: Rothfutch's Graph

JMF = A: B: C: D

The obtained gradation or proportioning of four materials used in BC Grade-II from graph A = 15 %, B = 15%, C = 20%, D = 50% (48% Quarry dust; 2% Mineral filler cement)

JMF = 15:15:20:50

MARSHALL STABILITY TEST:

Mix Design: (conventional BC grade-II mix)

Mould size- d = 0.105m, h = 0.67m

Area = $\pi d^2/4$

Volume = Area * height

Total mix weight W = Volume * Density

$V_v \% = 100*(G_t - V_b)/G_t$

$V_b \% = G_b * W_4/G_4$

$V_{MA} \% = V_v + V_b$

$V_{FB} = 100V_b/V_{MA}$

$G_b = W_A/W_A\text{-}W_S$

$G_t = 100/(W_1/G_1)+(W_2/G_2)+(W_3/G_3)+(W_4/G_4)$

Where,

Vv = air voids in the mix, %

V_b = volume of bitumen, %

V_{MA} = voids in mineral aggregates, %

V_{FB} = voids filled with bitumen, %

G_b = Bulk density of mix

Gt = Maximum theoretical density

W_A = Weight of specimen in air

W_S = Weight of specimen in water

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W_1 = % by weight of coarse aggregate in total mix = 15 %
W_2 = % by weight of fine aggregate in total mix = 15 %
W_3 = % by weight of filler = 20 %
W_4 = % by weight of bituminous binder = 48 %
G_1 = Specific gravity of coarse aggregates = 2.625
G_2 = Specific gravity of fine aggregates = 2.6
G_3 = Specific gravity of filler used = 2.610
G_4 = Specific gravity of coarse aggregates = 1.010

Table Vii: Observation And Tabulation For Marshall Stability Value Test

Sample No.	Bitumen content	Wt. of sample in air	Wt. of sample in water(g)	Dia (mm)	Height (mm)	Area	Volume (cc)	Density (g/cc)	Average	Stability value
1	5	1249.0 1262.0	711.00 714.00	100.0	64.67 65.67	7857.143	508.121 515.979	2.458 2.423	2.440	1543.70 1719.90
2	5.5	1258.0 1259.0	717.00 725.00	100.0	64.33 65.00	7857.143	505.450 510.714	2.489 2.471	2.480	1808.10 1741.95
3	6	1260.0 1259.0	729.00 728.00	100.0	65.30 65.00	7857.143	513.307 510.714	2.455 2.465	2.460	1146.60 1278.90
4	6.5	1263.0 1262.0	730.0 733.0	100.0	66.33 64.67	7857.143	521.164 508.121	2.423 2.434	2.454	1102.50 1168.65
5	7	1262.0 1267.0	731.0 732.0	100.0	65.00 67.00	7857.143	510.714 526.429	2.471 2.405	2.438	815.50 994.896

Table Viii: Observation And Tabulation For Flow Value, V_v, V_b

Correction factor	Stability (Kg)	Average	Flow value (mm)	Avg (mm)	G_t	G_b	V_v (%)	Avg (%)	Wt. of bitumen (%)	V_B (%)
1.000 1.000	1543.700 1719.900	1631.700	3.5 3.3	3.4	2.462 2.462	2.322 2.322	5.695 5.267	5.481	5.00	11.493 11.545
1.040 1.000	1860.429 1741.950	1811.18	3.7 3.5	3.6	2.445 2.445	2.325 2.35	4.899 3.886	4.392	5.00	12.663 12.793
1.000 1.000	1146.600 1278.900	1212.75	4.4 5.2	4.8	2.429 2.429	2.373 2.371	2.303 2.381	2.342	6	14.098 14.085
1.000 1.040	1102.500 1215.396	1158.94	5.00 5.00	5	2.413 2.413	2.390 2.386	1.795 1.130	1.463	6.5	15.250 15.353
1.000 0.960	815.850 994.896	905.37	6.1 5.9	6	2.397 2.397	2.377 2.371	0.863 1.108	0.936	7.00	16.472 16.431

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Table Ix: Observation And Tabulation For V_{ma}, V_{fb}

V_{MA} (%)	Avg (%)	V_{FB} (%)	Avg (%)
17.188 16.812	17.00	66.686 68.670	67.768
17.561 16.683	17.122	72.105 76.709	74.407
16.400 16.466	16.433	85.956 85.541	85.749
17.045 16.483	16.674	89.471 93.142	91.307
17.335 17.539	17.437	95.019 93.683	94.351

Table X: Observation And Tabulation For Optimum Bitumen Content

Criteria	Bitumen content %
Max Stability	5.5 %
Flow	5.8 %
V_V	5.6 %
Max Density	6.5 %
OBC	5.85 %

Optimum bitumen content of 60/70 grade (VG-30) bitumen = 5.85%
Maximum stability = 1808 kg, Flow value = 4 mm at bitumen content = 5.5%
Properties of bituminous mix after replacing 20 mm down size aggregates with 5 % waste plastic for 60/70 grade bitumen:

Table Xi: Marshall Stability Values Kg For Bc Grade Ii For Waste Plastic Of 5 %

Waste Plastic, %	Stability value, Kg	Flow value
5	1992	4.5 mm

Maximum stability = 1992 kg

Table xii: comparison between ordinary bituminous roads and waste plastic bituminous roads.

SL. No.	Properties	Plastic Road	Ordinary Road
1	Marshall Stability Value	More	Less
2	Binding Property	Better	Good
3	Softening Point	Less	More
4	Penetration Value	More	Less
5	Tensile Strength	High	Less
6	Rutting	Less	More
7	Stripping (Pot Holes)	No	More
8	Seepage-Of Water	No	Yes
9	Durability Of The Roads	Better	Good
10	Cost Of Pavements	Less	Normal
11	Maintenance Cost	Almost Nil	More
12	Environment Friendly	Yes	No

V. CONCLUSION

Recycled plastic along with aggregates is used for the better performance of roads. The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in reducing rutting, ravelling and there is no pothole formation. The roads can withstand heavy traffic and show better durability. Following are some points which are drawn from the study: The Aggregate Impact Value of 5 % plastic replaced bituminous mix is lower than aggregate coated with normal bitumen mix. These values are well within IRC limits (i.e. less than 30). This infers that plastic coated bitumen can resist greater impact and pavements coated with plastic have a longer lifetime The Water Absorption Capacity of plastic coated bitumen is lower than aggregate coated with normal bitumen mix. The values are within the IRC limits (i.e. less than 2). The value of absorption can be taken as negligible. The above results state that water absorption is very less in plastic coated bitumen, thus reducing infiltration eliminating the possibility of formation of potholes. The ideal plastic content which needs to be added is 5% weight of 20mm down size aggregates. The Marshall Stability value of plastic coated bitumen is 1.1 times greater than the one which is coated normal bitumen mix. This indicates the strength which plastic content imparts to the aggregate thus improving load carrying capacity with minimal deflection. Thus the analysis and results presented above shows that plastic obtained from municipal plastic waste, proved to be a better binder for pavements than normal bitumen. The properties displayed by plastic coated bitumen are beneficial without incurring much cost leading for effective, economic and efficient laying of roads. In this way plastic waste can be re-used

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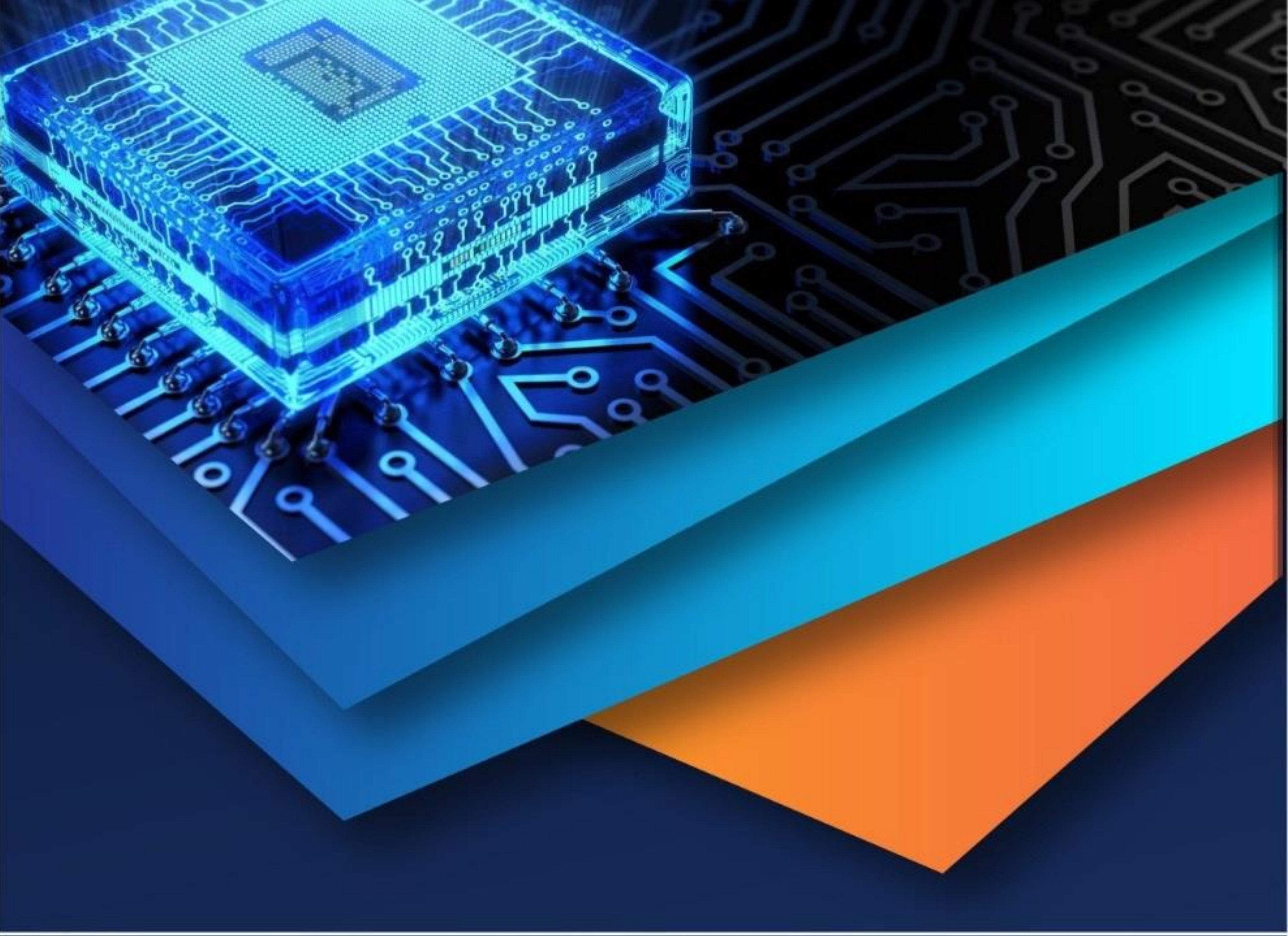

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