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Utilization of Waste Adhesives in Bituminous Concrete

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Abstract: In India due to rapid growth in urbanization leads to increased number of vehicles day by day on the road pavements which results in repeated loading and higher riding quality roads. Surface course is the top most layer of the flexible pavement which undergoes high stresses and wear and tear due to traffic loads. Hence it is necessary to construct the roads with higher quality materials and mean time the use of natural resources also should be reduced. In India increasing in population and vehicles lead to increased generation of waste products such as waste plastic and rubber tyres. In this paper an attempt has been made to use the crumb rubber (4%, 8%, 12% and 16%) and low density polyethylene (4%, 6%, 8% and 10%) waste as replacement for bitumen. The test results showed that addition of crumb rubber at 12% to bitumen and replacement of low density polyethylene at 10% to bitumen with 12% crumb rubber shows increased stability than conventional mixes.
Key words: Low density polyethylene, Crumb rubber, stone dust, bitumen, Marshall Test

I. INTRODUCTION

Roads play a vital role in modern society, which provides increased mobility for people, goods and services. Pavements act as a basic supporting structure in highway transportation system. It is the actual travel surface especially made durable and serviceable to withstand the traffic load which acts upon it. There are two types of pavement surface namely Flexible and Rigid pavement. Bituminous concrete is a flexible pavement made up of dense graded aggregates which is premixed and well compacted to form good surface course. It mainly consists of graded mineral aggregates bounded together by binder material called bitumen. The top layers of a flexible pavement, mainly the surface course has to resist high stress conditions and wear and tear due to traffic loads. In addition to this the surface course is exposed to adverse climatic factors including daily temperature variations, water, etc. Therefore, surface course should be properly designed with high quality materials to withstand traffic load as well as climatic factors.

On the other side generation of waste materials are increasing day by day. Analysis of results shows that annually o.6 million Tons tyres are generated as waste scrap tyres in the country. The manufacture of rubber tyre mainly contains highly toxic additives such as zinc, chromium, lead, copper, cadmium and sulphur. Also, it is estimated that about 9,205 tonnes of total plastic waste per day which is collected and recycled (approximately 60% of total plastic waste) and 6,137 tonnes remain uncollected and littered. These Waste materials requires more land to dump and produces more toxic gases during burning process which causes environmental pollution. Recently researches going on to utilize both waste tyre rubber and waste plastics as modifier in bituminous concrete.

II. LITERATURE REVIEW

Sharma et al (2013) conducted a study on flexible pavement with the use of waste tyre rubber. The authors were observed that Marshall Stability increases for increasing crumb rubber percentage of 8%, 10%, 12% and there after decreases at 5% optimum bitumen content. Maximum stability achieved at 12% was 1230.78kg with optimum binder .Test results shows that as percentage of crumb rubber increases, penetration value decreases which shows higher stiffens of sample

The significance of crumb rubber on rheological properties of bituminous mix was determined by **Praveen et al (2009).** Researchers found that as percentage of the crumb rubber 3%, 5%, 7% and 9% was added to 80/100 and 60/100 bitumen showed increased elastic behaviour of binder and reduced temperature susceptibility with increasing rubber content. The performance of crumb rubber by varying its sizes in modified bitumen was evaluated by **Nabin (2014).** For each sample 15% of crumb rubber by weight of bitumen for four different sizes such as coarse (1 mm - 600 μm); medium size (600 μm - 300 μm); fine (300 μm-150 μm); and superfine (150 μm - 75 μm) were evaluated using Marshall Stability tests and density void analysis tests. The sample with crumb rubber size (0.3-0.15mm) showed the highest stability value. **Sinan and Emine (2004)** evaluated the use of High Density Polyethylene (HDPE) in asphalt concrete. Modified binders was prepared by mixing AC-20 binder with powder form of HDPE of

4, 6 and 8% by the weight of optimum bitumen content of 4.5 % at mixing temperatures of 145oC,155o C and 165oC and 5, 15 and 30 min of mixing time. The researchers concluded that sample prepared with 4% of HDPE at 165oC with 30 min mixing time shows the highest stability of 21KN, smallest flow value of 3.8mm and higher values of Marshall Quotient. **Yadav et al (2013)** investigated the feasibility of waste plastic cement bags strips of size 2.36mm-4.75mm with varying percentage of 0% to 12% at increment of 2% by weight of an optimum bitumen content of 5% to bituminous concrete with CRMB 60 grade bitumen. It was found that as waste polypropylene content increases, stability increases up to 8% and thereafter decreases. Several studies have proven that the use of waste plastic and tyre rubber in bituminous mix improves its performance characteristics but there is no common opinion about the optimum dosage of the waste materials. Therefore in this study an attempt is made to investigate the dosage of waste plastic and tyre rubber in the design of an optimum bituminous mix.

III. OBJECTIVES OF THE STUDY

In the present work waste low density polyethylene and crumb rubber are used as a modifier for bitumen. The main objectives of this study are listed as follows.

A. To determine the basic properties of aggregates, bitumen, crumb rubber and plastic waste.

B. To determine optimum binder content (OBC) for Bituminous Concrete (BC) based on Marshall Properties.

C. To find optimum percentage of crumb rubber (ORC) by weight of bitumen in bituminous concrete mix.

D. To find optimum percentage of waste plastic (OPC) by partial replacement of bitumen in bituminous concrete mix.

IV. MATERIAL AND METHODOLOGY

The experiments were conducted in the laboratory on the materials which are used for bituminous mixes.

A. Aggregates

Aggregates are the primary constitutes materials used in the construction of pavements. They are mainly responsible for load transferring capabilities in pavements. Aggregate contributes up to 90-95 % of the mixture by volume and contributes to most of the load bearing and strength characteristics of the mixture. In the present study aggregates are obtained from local quarry. Physical properties of coarse aggregates are given in the Table 1.

TABLE 1. Properties of Aggregates

Properties	Results	IS Limits	Test method
Specific gravity	2.7	2.5 - 2.9	IS: 2386 (P III)
Water absorption of Aggregates (%)	0.48%	< 2	IS: 2386 (P III)
Crushing Value (%)	30.8%	< 30	IS: 2386 (P IV)
Impact Value (%)	12%	< 24	IS: 2386 (P IV)
Los Angeles Abrasion Value (%)	16%	< 30	IS: 2386 (P IV)
Flakiness Index (%)	12.86%	< 30	IS: 2386 (P I)
Elongation Index (%)	23.38%	< 25	IS: 2386 (P I)

B. Bitumen

Bitumen is the main raw material mainly responsible for distributing the traffic load into beneath surfaces even though aggregates bear the traffic load. Physical properties of binder are determined by conducting different tests on bitumen and the results are shown

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in the Table 2.

TABLE 2. Physical Properties of Bitumen

Tests	Test Method	Results
Penetration in mm	IS 1203-1978	69
Softening Point ^{0}C	IS 1205-1978	52
Ductility at 27^{0}C in cm	IS 1208-1978	76
Specific Gravity	IS 1202-1978	1.02
Flash point^{0}C	IS 1448 (P:69)	330
Fire Point^{0}C	IS 1448 (P:69)	350

C. Filler

A mineral filler is an inert material which passes through 75 micron sieve. The main function of filler is to fill the voids in coarse aggregates. Filler asphalt mastic acts a cementing agent which increases the resistance to movement of particles within the mix. In the present study crushed stone dust is used as mineral filler. The specific gravity of stone dust is 2.92.

D. Modifiers

In the present study low density polyethylene (Fig.1) and crumb rubber (Fig.2) are used as modifiers. Low density polyethylene (waste milk packets) is collected from local source and which are washed in hot water, dried and shredded into pieces of 4.75mm to 2.36mm size. Specific gravity of plastic is 0.915.The Crumb rubber is collected from Tyre resole shop and shredded into pieces of 0.3mm to 0.15mm. The specific gravity of crumb rubber is 0.96.

Fig.1 Low density polyethylene

Fig.2 Crumb Rubber

1) *Aggregate Gradation:* Aggregate gradation is an important characteristic which influences the properties of Hot Mix Asphalt (HMA) mixture as a pavement material. In the present study aggregate grading that satisfies requirement of MORTH 2009 specification of midpoint gradation–I is chosen. The aggregate gradation for nominal size of the aggregate is 19mm.
2) *Procedure to prepare Marshall samples:* Marshall Test includes determining stability and flow values of compacted specimen. Stability value indicates peak resistance load obtained when constant rate of deformation of sample takes place. Marshall Apparatus shown in the Fig.4.3. To prepare Marshall Specimens following procedure was adopted.

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a) Initially 1200gm of aggregates and filler were taken in pan and heated for 1hour in oven at 160^{0}c to 170^{0}c

b) Bitumen was heated at 155^{0}c to 165^{0}c and then added to the heated aggregates at a varying percentage of 5% to 7% at an interval of 0.25%.The mixture was thoroughly mixed at temperature 140^{o}C until all the aggregates are coated properly.

c) The mix was then transferred to preheated moulds of size 101.6mm dia and 63.5mm height and compacted with the rammer of 4.54 kg by giving 75 blows on each side of specimen (as per MORTH for heavy traffic).

d) The same procedure was repeated by adding crumb rubber with 4, 8, 12, 16% to bitumen and waste plastic with 4,6,8,10% by weight of bitumen to crumb rubber(ORC)- bitumen BC mix.

e) The compacted specimens were removed after 24hours from mould with the help of specimen extractor. Then diameter, length, height, weight in air and weight in water of the specimens are taken.

f) The Marshall properties such as stability, flow, air voids, voids in mineral aggregates and voids filled with bitumen were calculated.

V. RESULTS AND DISCUSSION

A. Optimum binder determination

Optimum binder content for BC mix is determined by considering maximum stability, maximum bulk density and percentage of bitumen at 4% air voids. In the present study control samples are prepared by varying percentage of bitumen 5% to 7% with 0.25%. Results of control mix are given in Table 3. Graphs are plotted to each Marshal properties and are shown in Fig .4 to Fig 9

TABLE 3 Results of Conventional Mix

Percentage of bitumen	5%	5.25%	5.5 %	5.75 %	6%	6.25 %	6.5 %	6.75 %	7%
Marshall stability(kN)	21.29	21.45	22.2	22.03	17.76	17.45	13.92	12.27	9.31
Flow value(mm)	3.5	3.7	4	4.2	3.18	2.3	2.2	3.9	2.4
Bulk density(gm/cc)	2.347	2.351	2.356	2.368	2.373	2.367	2.357	2.360	2.358
Air voids, Vv (%)	5.7	5.0	4.8	4.0	3.46	3.38	3.24	3.0	2.8
Voids in mineral aggregate	17.2	17.10	17.50	17.35	17.42	17.88	18.26	18.62	18.98
Voids filled with bitumen	66.86	70.76	72.57	76.95	80.14	81.10	82.3	83.88	85.25

From the Fig 4 to Fig 6 it is observed that maximum stability is at 5.6%, maximum density is at 6% and at 4% air voids bitumen content is 5.75%. .Based on this the optimum bitumen content for BC mix is 5.75%.The Voids Filled with Bitumen (VFB) at 5.75% is 76.95% which is more than MORTH requirement (65-75%). Hence 5.5% is considered as optimum bitumen content which satisfies MORTH Specification shown in Fig. 7 to Fig. 9.

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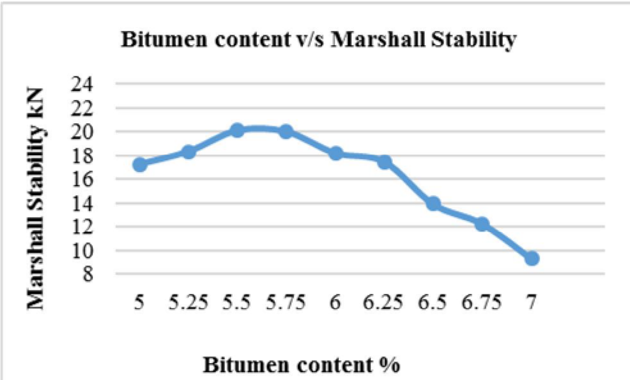

Fig 4 Bitumen% v/s stability

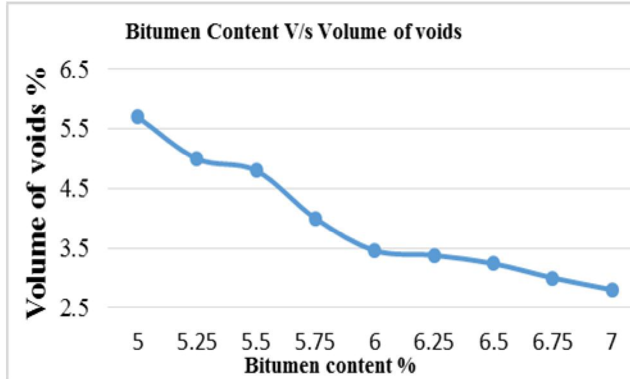

Fig 5 Bitumen% v/s air voids

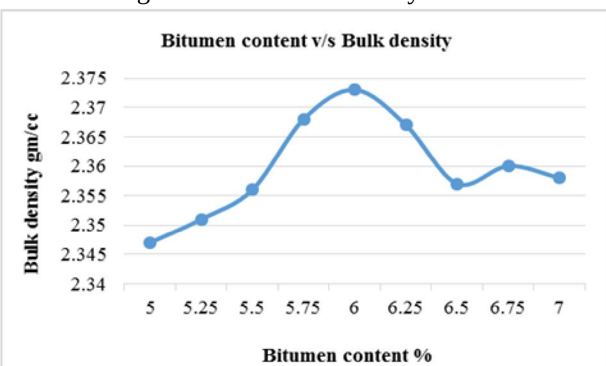

Fig 6 Bitumen% v/s Bulk density

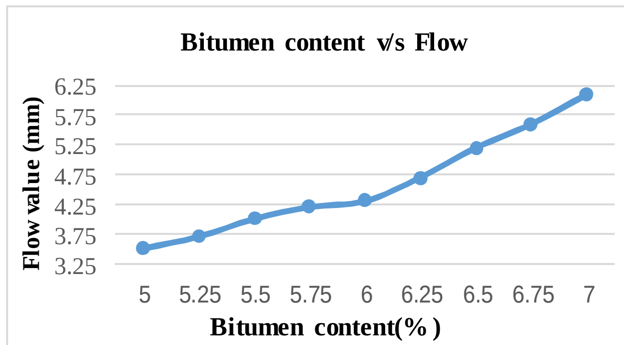

Fig 7 Bitumen% v/s Flow

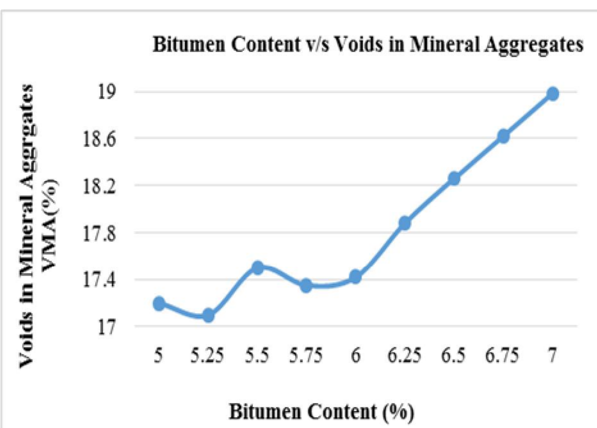

Fig 8 Bitumen % v/s VMA

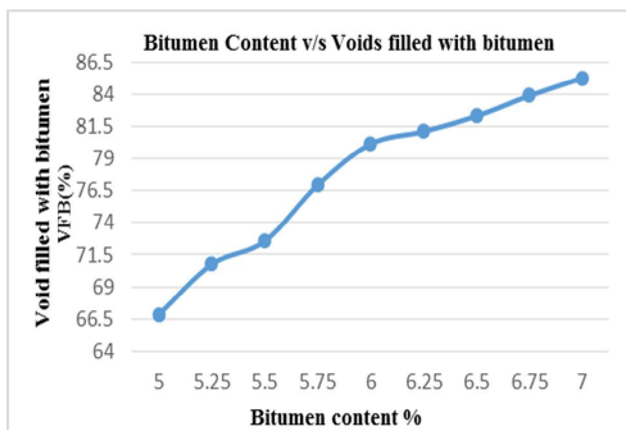

Fig 9 Bitumen % v/s VFB

B. Determination of optimum rubber content and optimum Plastic content in rubber –bitumen BC mix

Marshall Test results of conventional mix and modified mixes are tabulated in the Table 4. It is clear from the Table that Addition of crumb rubber to the optimum binder content shows increased trend of stability up to 12% and thereafter decreased. Maximum stability obtained at 12% of crumb rubber is 22.56 KN which is higher than conventional mix. Partial replacement of Low density Polyethylene to the optimum binder content (5.5%) at optimum rubber content (12%) shows that increase in stability compare to conventional mix but lower than crumb rubber modified mix. In Polyethylene modified mix as plastic content increases stability also increased. The Stability value obtained at 10% plastic content is 22.40 KN which has been considered as optimum value.

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TABLE 4. Marshall Test Results of Modified B C mixes

BC mix	Conventional mix	Crumb Rubber				Plastic			
	OBC (5.5%)	4%	8%	12%	16%	4%	6%	8%	10%
Marshall stability kN	20.10	20.12	21.22	22.56	19.36	18.65	20.90	21.86	22.35
Flow in mm	4	2.6	2.8	3.2	2.9	3	2.85	2.63	2.5
Bulk density g/cc	2.356	2.358	2.351	2.348	2.343	2.332	2.318	2.334	2.343
Air voids %	4.8	5.1	4.3	4.1	3.3	4.8	5.3	4.7	4.3
VMA %	17.5	17.11	16.55	16.16	16.03	17.37	17.79	17.28	16.93
VFB %	72.57	74.22	74.63	75.48	79.60	72.36	70.20	72.80	74.60

VI. CONCLUSIONS

Based on the experimental investigation the following conclusions are drawn:

The results indicated that the use of waste tyre rubber and plastic in bituminous concrete mixtures shows improved properties. The bitumen modified with 12 % rubber and 10% plastic with 12% rubber are showing better performance as compared to conventional mix. The Marshall Stability which is a strength parameter has shown increasing trend with a maximum increase percent of 12.24% as compared to conventional mix when modified with 12 % rubber Waste and 11.2% when modified with 10 % plastic. The waste plastic used in the mix will get coated over aggregates of the mixture and reduces porosity and improves binding property. The use of this percentage of these wastes in road construction will solve the problem of their disposal and provide a better flexible pavement with improved performance.

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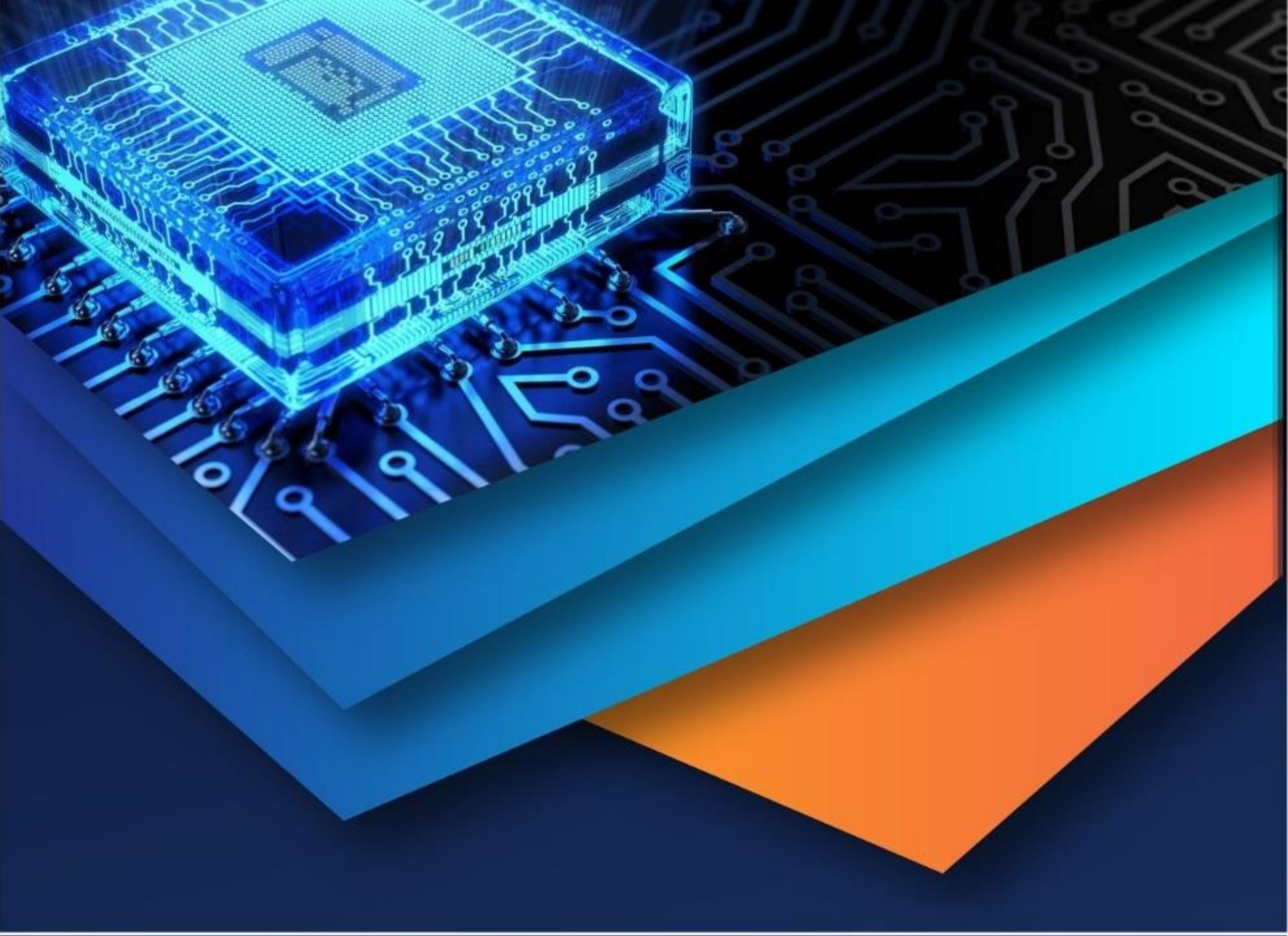

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