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Utilization of Copper Slag in Bituminous Concrete with a Stone Dust and Flyash as a Filler Material

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Abstract: ***In this paper an attempt has been made to utilize the copper slag, stone dust and fly ash in bituminous concrete. The copper slag is produced as waste from roasting of copper, in which sulphur is eliminated. Copper slag is used as a fine aggregate by varying the percentage from 10%, 20% and 30% with stone dust and fly ash as a filler material. Marshall test has been considered for the purpose of mix design as well as evaluation of paving mixes. The Marshall property such as stability, flow value, % of air voids, void filled in mineral aggregate (VMA), void filled in bitumen (VFB) and optimum bitumen content was found***
Key words: copper slag, stone dust, fly ash, Marshall Test.

I. INTRODUCTION

Bituminous concrete is a type of construction material used for paving roads, driveways, and parking lots. It's made from a blend of stone and other forms of aggregate materials joined together by a binding agent. This binding agent is called "bitumen" and is a by-product of petroleum refining. It has a thick, sticky texture like tar when heated, and then forms a dense solid surface once it dries. Bitumen composed primarily of highly condensed polycyclic aromatic hydrocarbons, containing 95% carbon and hydrogen (± 87% carbon and ± 8% hydrogen), up to 5% sulphur, 1% nitrogen, 1% oxygen and 2000 ppm metals. Also bitumen is mixture of about 300 - 2000 chemical components, with an average of around 500 - 700. It is the heaviest fraction of crude oil, the one with highest boiling point (525°C). Various Grades of Bitumen used for pavement purpose: 30/40, 60/70 and 80/100. Bituminous concrete is also widely known as asphalt in many parts of the world. a bituminous paving mixture is a mixture of coarse aggregate, fine aggregate and bitumen mixed in suitable proportion to result strong and durable mix to with stand traffic load ,Suitable material combinations and modified bituminous binders have been found to result longer life for wearing courses depending upon the percentage of filler and type of fillers used. In India, huge quantity of naturally available materials like soils and aggregates are being utilized for road construction. Rapid industrialization and large scale infrastructural development in India, has resulted in huge scarcity of construction materials. Use of waste materials like copper slag, zinc slag, steel slag, jarofix, Phospho-gypsum, red mud, Kimberlite, lime sludge and coal ash in road construction would definitely solve this problem to an extent and would definitely provide an alternative to conventional materials. Also, the limited use of these materials has created huge heap of waste dumps inside the plant premises causing environmental pollution. The copper slag (CS) is produced as waste from roasting of copper in which sulphur is eliminated. Copper slag (CS) was used as a fine aggregate in the design of bituminous mixes like bituminous macadam, dense bituminous macadam, bituminous concrete and semi-dense bituminous concrete. Fly ash is a mineral by-product of coal combustion in thermal power projects. Fly ash of are used as a filler in bituminous concrete.

II. LITERATURE REVIEW

Pundhir et al (2005) studied that the copper slag (CS) was used as a fine aggregate (up to 30%) in the design of bituminous mixes like bituminous macadam, dense bituminous macadam, bituminous concrete and semi-dense bituminous concrete. Marshall Method of mix Design is adopted in which CS and stone dust as fine Aggregate and hydrated lime as a filler. OBC for different mixes was found as follows BM, 3.5, DBM, 5.3, BC, 5.9, and SDBC, 5.9%. Addition of CS a fine aggregate in various bituminous mixes provides good interlocking and eventually improves volumetric and mechanical properties of bituminous mixes. Because of improved property by the incorporation of copper slag it can be used as a fine aggregate in bituminous mixes as the substitute of crusher dust as fine aggregate.

Havanagi et al (2012) The waste like copper slag, zinc slag, steel slag and pond ash were investigated for their suitability in road embankment and sub grade layers, while copper slag and zinc slag may be used as a partial replacement of fine aggregate for the construction of sub base, base and bituminous layers. The specific gravity of copper slag, zinc slag and steel slag varied in the range of 2.75 – 3.6, while pond ash exhibited low value of specific gravity of 2.27. The bulk density of Marshall Samples

varied in the range 24.4 kN/m3 to 25.6 kN/m3, Marshall stability value in the range 8.7 kN to 14.7 kN, Flow value in the range 3 mm to 4 mm, % air voids value in the range 4.13 to 7.19 and optimum bitumen content varied in the range 3.4 % to 7.19 %. Copper slag and zinc slag materials can be used as a replacement of fine aggregate in sub base, base (WMM) and bituminous layers of road pavement. The amount of replacement varies from 20 to 30 % in WMM mix and 10 - 25 % in the bituminous mixes.

Kajal et al (2007) Study present the use of waste plastic and copper slag in hot bituminous mix to enhance pavement performance, bituminous mixes were prepared by mixing of graded mineral aggregate and increasing percentage of binder content 5.0,5.5,6.0,6.5% by wt. of mineral aggregate. Optimum binder content is achieved at 5.2% by weight of mineral aggregate specimens are also prepared with composition of CS(10,15,and 20%) replacing stone dust ,CS(15%)has been found best.

Debashish Kar et al (2014) Were Investigated the influence of fly-ash as a filler in bituminous mixes , For comparison, control mixes with cement and stone dust have also been considered. Marshall test has been considered for the purpose of mix design as well as evaluation of paving mixes. Marshall stability and unit weight increase with bitumen content up to 5% after which these two parameters decrease. At any bitumen content the stability value and unit weight are highest for mixes with cement as filler followed by that with stone dust and fly ash. flow value increases with bitumen content. However, the flow value is lowest for mixes with cement as filler compared to stone dust and fly ash. In the similar manner the air void decreases with increase in bitumen content. However it is to be highlighted that the fly ash causes maximum reduction of air voids compared to the other two fillers. Hence, it is generally concluded that the fly ash can effectively be used as filler in paving mixes in place of most commonly used fillers such as ordinary Portland cement and stone dust.

III. MATERIAL AND METHODOLOGY

A. Materials Used

1) Bitumen: The bitumen used in this study was tested in the laboratory. The physical properties such as Penetration, Ductility, Softening Point and Specific Gravity were evaluated and the results are tabulated in Table 3.1**.**

Property Tested	Results
Penetration (100 gram, 5 seconds at 25^0C) ($1/10^{th}$ of mm)	64
Softening Point , ^{0}C(Ring & Ball Apparatus)	44
Ductility at 27^0C (5 cm /minute pull), cm	63.4
Specific Gravity	1.01
Flash point, ^{O}C	310
Fire Point, ^{O}C	330

Table 3.1 Physical Properties of (60/70) VG 30 Penetration Grade Bitumen

2) Aggregates: The aggregates present in BC should be highly durable, strong and toygh to resist heavy loads. They undergo internal friction and high rubbing; hence the physical properties of these aggregates should be given high importance. Aggregates having sufficient strength, hardness, toughness, specific gravity and shape are chosen. The properties of aggregates used in the present study are tabulated in Table 3.2.

Aggregate grading that satisfied the requirement of the Ministry of Road Transport and Highways (MoRT&H, 2001) specification for midpoint gradation for Grading- II of Bituminous Concrete were selected

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Property Tested	Results
Aggregate Impact Value	24%
Los Angeles Abrasion Value	14.2%
Water Absorption Value	0.84%
Specific Gravity	2.69
Combined Flakiness and Elongation Index	28.2 %

Table 3.2 Properties of Aggregates

B. Aggregate Gradation Adopted

Aggregate grading that satisfied the requirement of the Ministry of Road Transport and Highways (MoRT&H, 2001) specification for midpoint gradation for Grading- II of Bituminous Concrete were selected

C. Design Of Bituminous Concrete Mix

The properties of any bituminous mix like stability, bulk density, air voids, are mainly dependent on the gradation of aggregates, binder content and its type, the type of compaction and compaction temperature. Marshall's Method of mix design as per ASTM D-1559 was adopted for this study. The Marshall Test specimens were prepared by adding 5.0, 5.5, 6.0, 6.5, and 7.0 per cent of bitumen by weight of aggregates. Following procedure was adopted to prepare the samples:

The aggregates were proportioned and mixed (aggregate and filler contribute to 1200gm). The aggregates were heated to temperature of 140^0C-165^0C.

The bitumen heated to140^0C to 160^0C was added in required quantity i.e., 5.0, 5.5, 6.0, 6.5, and 7.0 per cent by weight of aggregates and was thoroughly mixed at a desired temperature of 155^0C.

The mix was placed in preheated mould of 10.16 cm diameter and 6.35 cm height with a base plate.

After leveling the top surface, the mix was compacted by a rammer of 4.54 kg weight and 45.7 cm height of fall with 75 blows on either side at temperature of 100^0C-115^0C.

Three specimens were prepared for different bitumen content (4.5, 5.0, 5.5, 6.0, 6.5 and 7.0, per cent) by weight of aggregates.

Compacted specimens were removed after 24 hours using specimen extractor.

The diameter, mean height, weight in air and weight in water of the specimens were noted.

IV. RESULTS AND DISCUSSIONS

The Following Graphs shows the result the Marshall properties such as Marshall stability, Flow, Bulk Density, volume of voids, voids in mineral aggregate, voids filled with bitumen

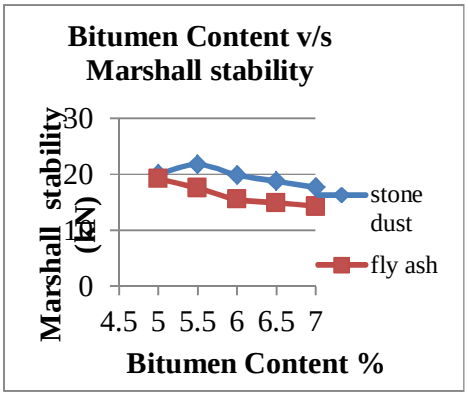

Fig 4.1.: The Marshall stability value is highest for the mix with stone dust as a filler followed by fly ash the stability value decrease with increase in bitumen content.

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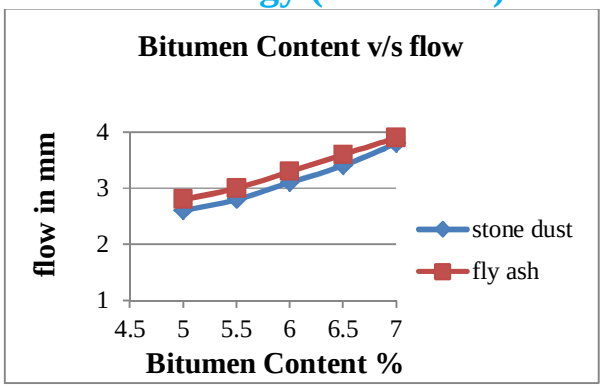

Fig 4.2 As the bitumen content increase the flow value also increase, the flow in stone dust as less then fly ash.

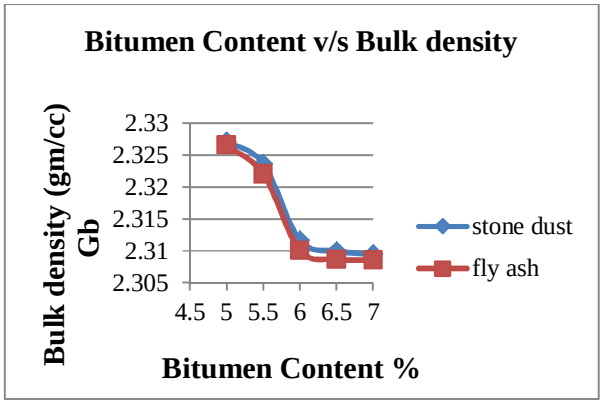

Fig 4.3As the bitumen content increase the bulk density decrease, the bulk density in stone dust as higher then fly ash.

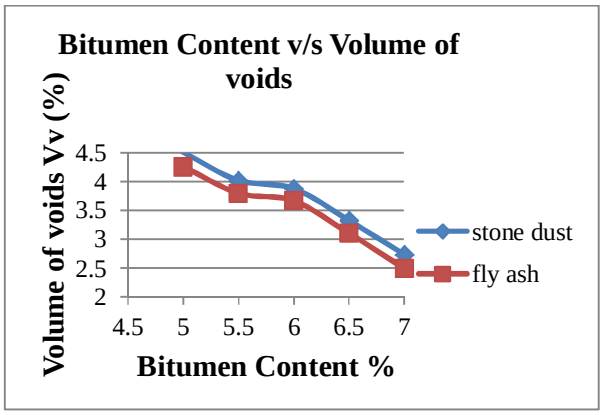

Fig 4.4 As the bitumen content increase the volume of voids decrease, the volume of voids in stone dust as higher then fly ash.

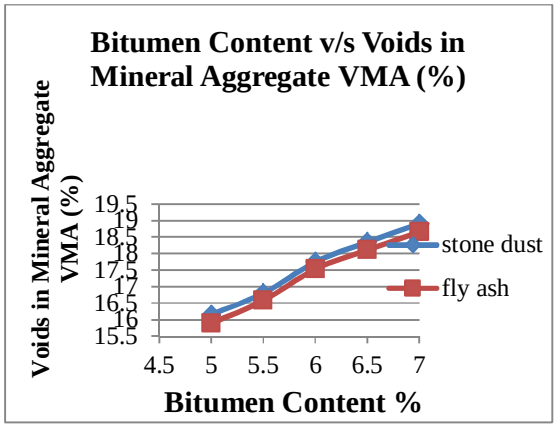

Fig 4.5 As the bitumen content increase the voids in mineral aggregate also increase, the mineral aggregate in stone dust as

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higher then fly ash.

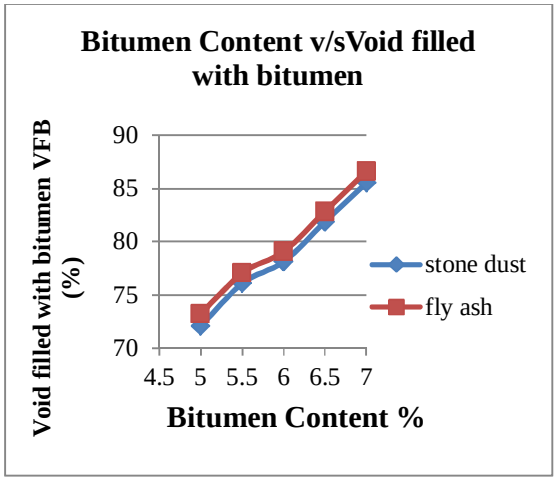

Fig 4.6 As the bitumen content increase the voids filled with bitumen also increase, the voids filled with bitumen in stone dust as less then fly ash.

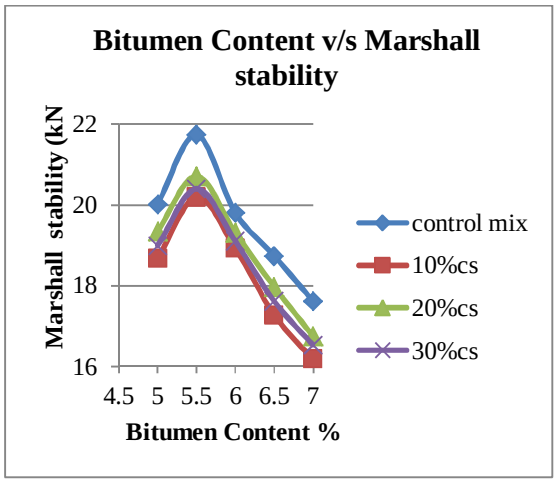

Fig 4.7.: The Marshall stability value is highest for the control mix with stone dust as a filler followed by copper slag, the stability for the 20% addition copper slag is higher then 10% and 30% value.

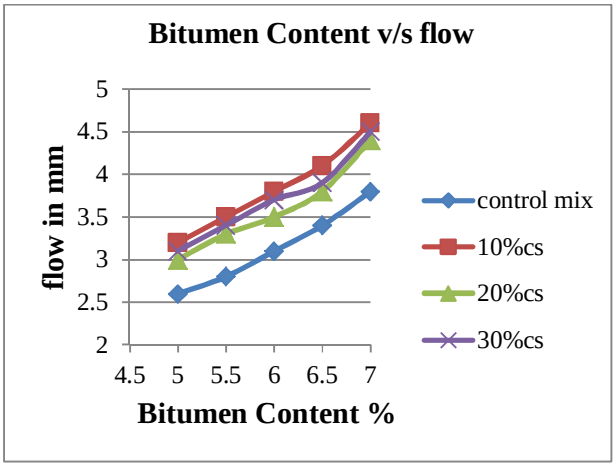

Fig 4.8 As the bitumen content increase the flow value also increase, the flow value for 10% cs is higher than the 20%, 30% cs and control mix.

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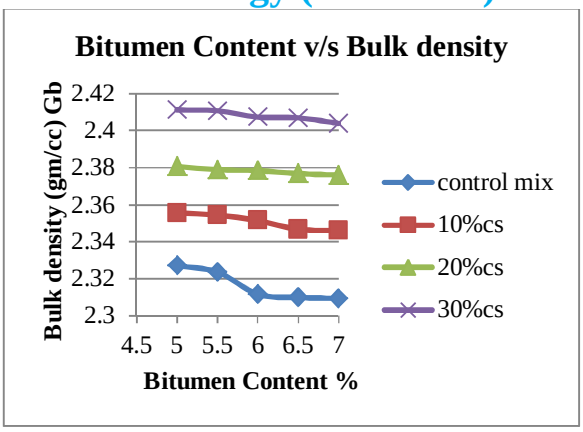

Fig 4.9 As the bitumen content increase the bulk density decrease, the bulk density for the 30% cs is higher than 20% ,10%and control mix.

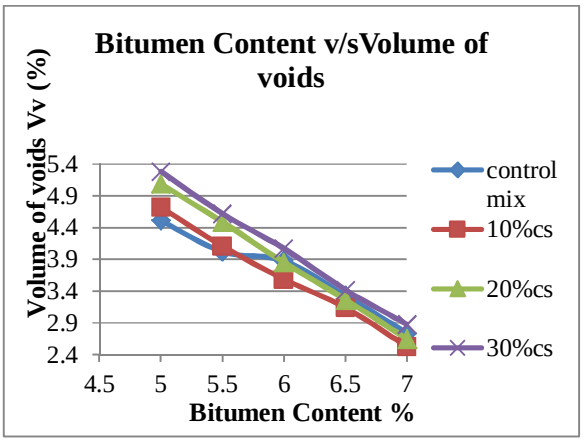

Fig 4.10 As the bitumen content increase the volume of voids decrease, the volume of voids for the 30% cs is higher than 20% ,10%and control mix.

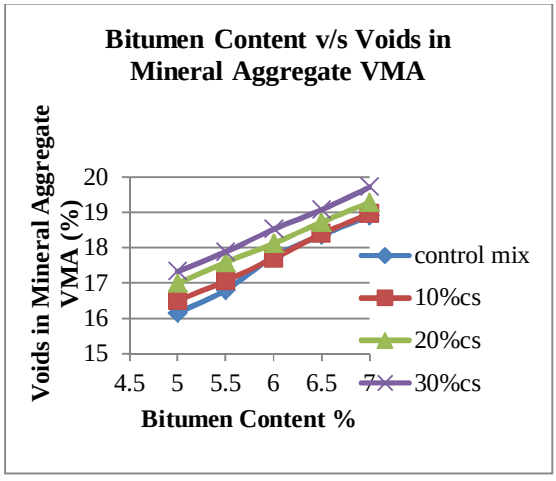

Fig 4.11 As the bitumen content increase the voids in mineral aggregate also increase, the voids in mineral aggregate for the 30% cs is higher than 20% ,10%and control mix.

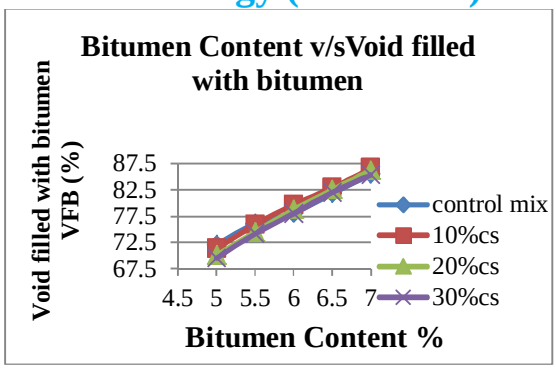

Fig 4.6 As the bitumen content increase the voids filled with bitumen also increase, the voids filled with bitumen in control mix as higher then 10cs,20,and 30cs%.

V. CONCLUSION

The Marshall stability is higher for the stone dust as a filler material as compared to the fly ash mix. With the addition of the copper slag, to the bitumen mix as a replacement of fine aggregate the stability for the 20%of the copper slag is higher then 10%and 30%.

As the bitumen content increases the flow value increases.

The bulk density increases with the addition of copper slag to the mix due to the fact that the specific gravity of copper slag is high compared to the specific gravity of natural aggregate.

The volume of voids is lower when fly ash is used as the filler material. This is due to the fact that fly ash being too fine having highest surface area fills the voids more effectively.

The voids in the mineral aggregate and void filled with bitumen increases with the increase in the bitumen content.

Due to the use of fly ash and copper slag in the bituminous mix, the disposal problem and the environmental problem can be reduced to certain extent.

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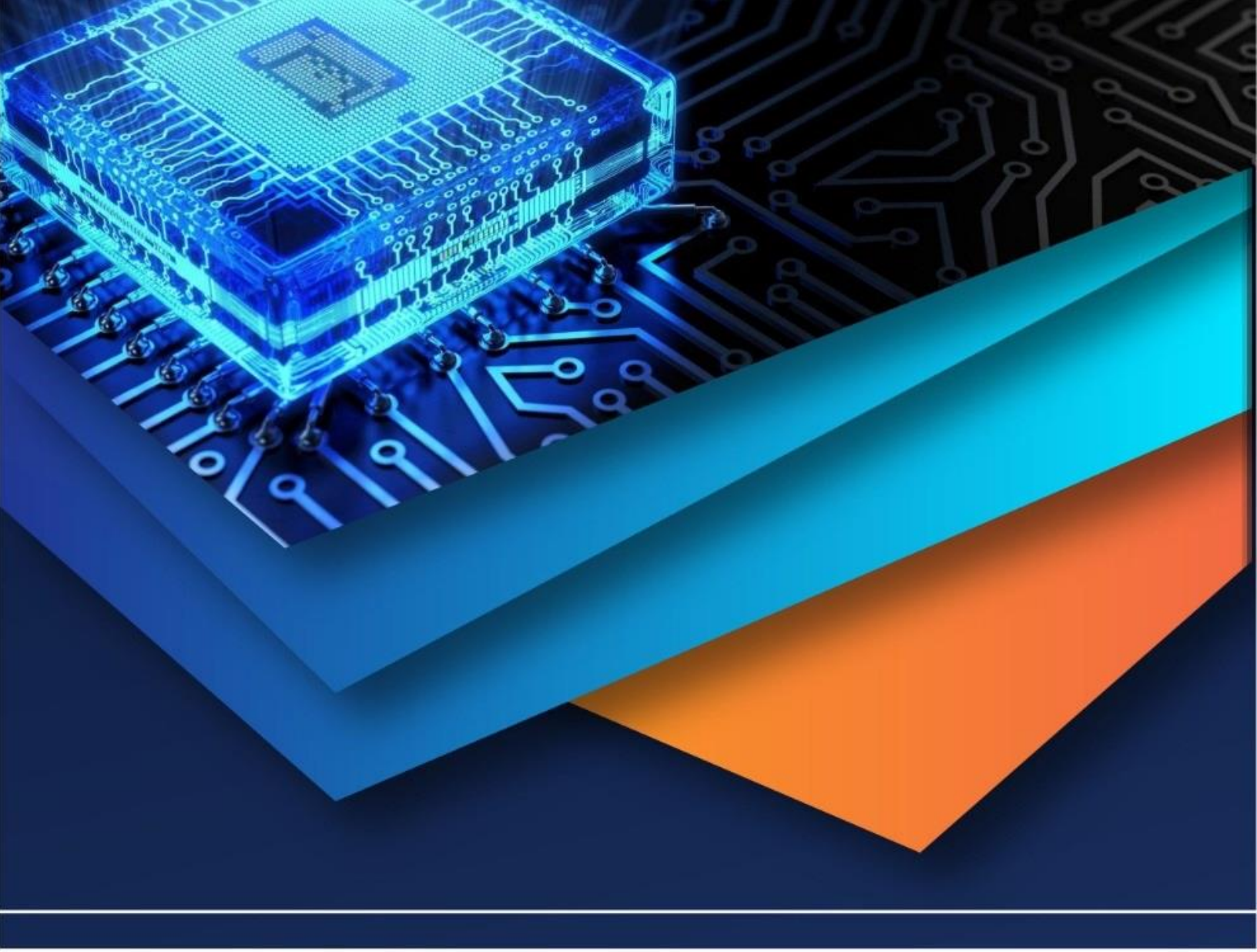

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