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Study of Economics and Stability of Bituminous Road by using Waste Plastic

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Abstract: ***Plastics are user friendly but not eco-friendly as they are non-biodegradable. The plastic waste in municipal solid waste is increasing due to an increase in the population. The disposal of plastic waste is becoming a major problem as they are intentionally made to resist to various conditions such as light, heat, chemicals, pathogen etc. to make it convenient to uses for various applications. The one of the efficient and cost effective disposal of waste plastic is using it as a binder for Bitumen which can be used for the pavement of road construction. The experiments are conducted by adding various percentages of waste plastic to Bitumen to evaluate the effect of this plastic on the properties of bitumen. The mixture shown the better binding property, stability, density and more resistant to water, it shown an improvement in the flash point and fire point also, implies that it can withstand high temperatures compare to pure bitumen. The total construction cost can also be reduced as some amount of bitumen is being replaced with waste plastic which is cheaper compared to bitumen.***
Keywords: ***Bituminous mix, low density polyethylene, Marshall Stability test, pavement***

I. INTRODUCTION

Plastic is a very versatile material, due to an industrial revolution and its large scale production, plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, electronics, electrical, building construction, communication sectors has been virtually revolutionized by the applications of plastics. Plastic is a non-biodegradable material and researchers are found that the material can remain on earth for 4500 years without degradation [1]. Several studies have proven the health hazard caused by improper disposal of plastic waste. The health hazard includes reproductive problems in human and animal, genital abnormalities etc. Looking forward the scenario of present life style a complete ban on the use of plastic cannot be put, although the waste plastic taking the face of devil for the present and future generation. We cannot ban use of plastic but we can reuse the plastic waste [2].

Now a day's disposal of different wastes plastic produced from different applications is a great problem, these materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. The threat of disposal of plastic will not solve until the practical steps are not initiated at the ground level. It is possible to improve the performance of bituminous mix used in the surfacing course of roads. The studies reported on the use of re-cycled plastic, mainly polyethylene, in the construction of blended roads indicated reduced permanent deformation in the form of rutting and reduced low temperature cracking of the pavement surfacing. The field tests withstood the stress and proved that plastic wastes used after proper processing as an additive would enhance the life of the roads and also solve environmental problems [3].

Based on the physical properties plastics are classified into thermo setting and thermo plastic. Thermo Plastic is used for manufacturing of packaging materials which contains polymers such as high and low density Polyethylene and Polystyrene [4]. Bitumen is viscous liquid, or a solid consisting essentially of hydrocarbons and their derivatives, which is substantially nonvolatile and softens gradually when heated. It is black or brown in color & possesses waterproofing and adhesive properties. It is obtained by refinery processes from petroleum, and is also found as a natural deposit or as a component of naturally occurring asphalt, in which it is associated with mineral matter [5,6].

II. PROCESS OF PLASTIC ROAD LAYING

This process starts with the collection of plastic waste from various places like dump yards. Then they have to be segregated and stored in a safe place. The plastic waste (bags, cups, water bottles etc...) which is collected is cleaned and dried for some time. Such plastic waste which is composed of PE, PP, and PS is shredded into sizes ranging 2.36mm to 4.75mm. Shredding can be done using shredding machine. PVC should be eliminated because of its highly toxic nature.

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Fig. 2 Shredding of Waste Plastic

Then aggregates should be selected based on the requirements of the road construction. In dry-process the aggregate mix is heated to 165^{o}C and transferred to mixing chamber. Monitoring the temperature is very important otherwise the desired properties of the aggregate may vary. In mixing chamber shredded plastic is added to the hot aggregates for 45sec and mixed uniformly at the surface of the aggregate. Then all plastics are get coated uniformly over the aggregate within 30 to 60 seconds which looks like oily in nature. The plastic is also heated 65^{o}C such as the bitumen to prevent weak bonding and have good binding property.

Fig.3Mixing of waste plastic with bitumen

In mixing chamber coated aggregate is mixed with hot bitumen at temperature ranges from 155^{o}C-165^{o}C, that resulted mix is used for the road construction. The road laying temperature is between 110^{o}C-120^{o}C. The roller is used for this road construction is 8-ton capacity.

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Fig. 4 Polymer Coated Bitumen Mix

There are two different field trails involved in the process of road laying namely dry and wet processes used for bitumen mix in a flexible pavement.

A. Dry Process

In this process the hot stone aggregate (170^{o}C) is coated with plastics and then mixed with hot bitumen (160^{o}C) and this mixes used for road laying. When coated with plastics the road quality is improved with respect to voids, moisture absorption and soundness. The plastic coating decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavements. This process is used for the isolated works.

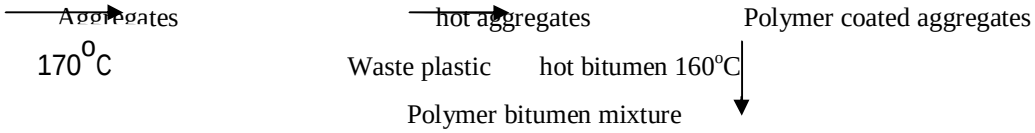

Fig.5 Flow chart of dry process

This test is used for plastic materials only. There are many advantages with this process such as

1) The plastic roads laid using dry process can survive for 5-6 years without any degradation.
2) Plastic coated with plastics improved its quality with respect to voids, moisture absorption.
3) This coating of plastic will increases the bonding and strength of mix.
4) The stone heating temp (170^{o}C) is same as road laying temperature.
5) Maximum 15% of waste plastic can be used as a binder for the road construction.

B. Wet Process

In this process waste plastic is grounded and made into powder. 6 to 8 % plastics mixed with the bitumen. Plastic increases the melting point of the bitumen and makes the road retain its flexibility during winters resulting in its long life. Shredded plastic waste acts as a strong “binding agent” for tar making the asphalt last long. By mixing plastic with bitumen the ability of the bitumen to withstand high temperatures increases.

The plastic waste is melted and mixed with bitumen in a particular ratio. Normally, blending takes place when temperature reaches 45.5^{o}C but when plastic is mixed, it remains stable even at 55^{o}C tests at the laboratory level proved that the bituminous concrete mixes prepared using the treated bitumen binder fulfilled all the specified Marshall mix design criteria for surface course of road pavement.

III. MATERIAL AND METHODOLOGY

A. Materials

Materials used in this work are aggregates were passed through 12.5 mm sieve and retained on 10 mm sieve. Bitumen 80/100 which has characteristics of this grade confirm to that of S 90 grade of IS-73-1992. This is the softest of all grades available

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in India. It is suitable for low volume roads and is still widely used in the country**.** The plastic waste (bags, cups, water bottles etc...) which is collected is cleaned and dried for some time. Plastic waste which is composed of PE, PP, and PS is shredded into sizes ranging 2.36mm to 4.75mm.

B. Penetration Index

The experiment was conducted to find how the addition of plastic effecting the penetration index value of bitumen. Initially experiment was carried out to find the grade of the bitumen by finding penetration index value. The semisolid bitumen was heated up to 160 ^{o}C, plastic was added and the mixture was poured in a small bowl, allowed it cool in water bath at room temperature for 1 to 1.5 hours before the test.

C. Softening point

The experiment was conducted to find at what temperature the plastic added bitumen is getting soften. It was carried out by melting the bitumen and casted into discs of two numbers in standard rings. The steel ball was kept on each casted disc of bitumen and the whole stand carrying these two discs was immersed in water bath. The temperature at which sample detaches from the die and falls indicates the softening point of the plastic-bitumen mixture.

D. Ductility

The experiment was conducted to find how the addition of plastic effecting elongation strength of the bitumen. Initially the semisolid bitumen was heated up to 160^{o}C; plastic was mixed to bitumen at this temperature and stirred it for uniform mixing. This mixture was filled in the mold and kept it cool in the water bath. The ductility value was achieved by measuring the distance between initial position the distance where the rupture took place.

E. Flash and Fire point test

The experiments were conducted out to find the flash point and fire point of the plastic added bituminous. The flash point of a material is the lowest temperature at which the vapor of substance momentarily takes fire in the form of flash under specified condition of test whereas the fire point is the lowest temperature at which the material gets ignited and burns under specified condition of test. The heating of bitumen was done at a rate of 5^{o}C to 6^{o} C per minute. The stirring was done at a rate of approximately 60 revolutions per minute. The test flame was applied at intervals depending upon the expected flash and fire points, and the temperatures were noted where the flash was just appears and disappears for flash point and the temperature at which this flash present for few seconds for fire point.

F. Marshall Stability:

In the Marshall test method three compacted samples are prepared for each binder content. The coarse aggregate, fine aggregate, and the filler material should be proportioned so as to fulfill the requirements of the relevant standards. The required quantity of the mix is taken so as to produce compacted bituminous mix specimens of thickness 63.5 mm approximately. 1200g of aggregates and filler were required to produce the desired thickness. The aggregates were heated to a temperature of 175° to 190°C. The compaction mould assembly and rammer are cleaned and kept pre-heated to a temperature of 100°C to 145°C. The bitumen is heated to a temperature of 121°C to 138°C and the required amount of first trial of bitumen is added to the heated aggregate and thoroughly mixed. The mix is placed in a mould and compacted with number of blows specified. The sample is taken out of the mould after few minutes using sample extractor.

In conducting the stability test, the specimen is immersed in a bath of water at a temperature of 60° ± 1°C for a period of 30 minutes. It is then placed in the Marshall Stability testing machine and loaded at a constant rate of deformation of 5 mm per minute until failure. The total maximum in kN (that causes failure of the specimen) is taken as Marshall Stability.

IV. COST BENEFIT ANALYSIS

Based on the Composition of the aggregate, grade of the bitumen and thickness of layer bitumen roads are classified Dense Bituminous Macadam, Bituminous Macadam. Calculations are done with 10 % bitumen replaced with waste plastics for above different types of bitumen roads. The technology of road lying is very much the same as prescribed by the Indian Roads Congress (Section 500, IV revision) Specifications. When the cost of plastic is compared with cost of bitumen it is very cheap and highly available. In the given table the cost reduction for 25mm SDBC (Semi dense bituminous concrete) analysis for 10 m^{2}area is shown.

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Table I Cost Comparison of Plain Bitumen Road and Plastic Bitumen Road

Material Needed	Plain- Bitumen road	Plastic-Bituminous roads
80/100 Bitumen	11250Kg	10125Kg
Plastic waste	-----	1125Kg
Cost	Rs. 393750	(BIT)Rs.354375 + (plastic)Rs.13500 = Rs. 367875
Cost Reduced	NIL	Rs. 25875.00
Saving of Municipal Solid Waste	NIL	1125 Kg of waste plastic.

V. RESULTS AND DISCUSSION

From the experimental results as shown in Fig.6 and Fig.7 it is observed that an increase in the percentage of polymer decreased the penetration value. This shows that the addition of polymer increases the hardness of the bitumen. The decrease in the penetration values depends on the percentage of polymer and the type of polymer that is being added. The ductility decreased by the addition of plastic waste to bitumen, the decrease in the ductility value may be due to interlocking of polymer molecules with bitumen. Flash and fire point increased with the increase in the percentage of polymer hence the polymer bitumen blend road surfaces will less affected by fire hazards. This shows that the blend has better resistance towards water. This may be due to better binding property of the polymer-bitumen blend. The softening point increased by the addition of plastic waste the bitumen, higher the percentage of plastic waste added, higher is the softening point. The influence over the softening point may be due to the chemical nature of polymers added. The increase in the softening point shows that there will be less bleeding during summer. Bleeding accounts, on one side, increased friction for the moving vehicles and on the other side, if it rains the bleedings accounts for the slippery condition, both these adverse conditions are much reduced by polymer-bitumen blend.

Table 2 Variation of Properties of Bitumen with % of plastic replaced

.S.No	% of Plastic	Penetration Index (mm)	Softening point (^{o}c)	Ductility (cm)	Flash point(^{o}c)	Fire point(^{o}c)
1	0	10.5	46.5	51.2	160	215
2	5	8.5	53	22	168	238
3	8	5.5	59	11.5	173	247
4	10	1.06	64	8.9	185	263
5	12	0.43	69	3.3	193	271

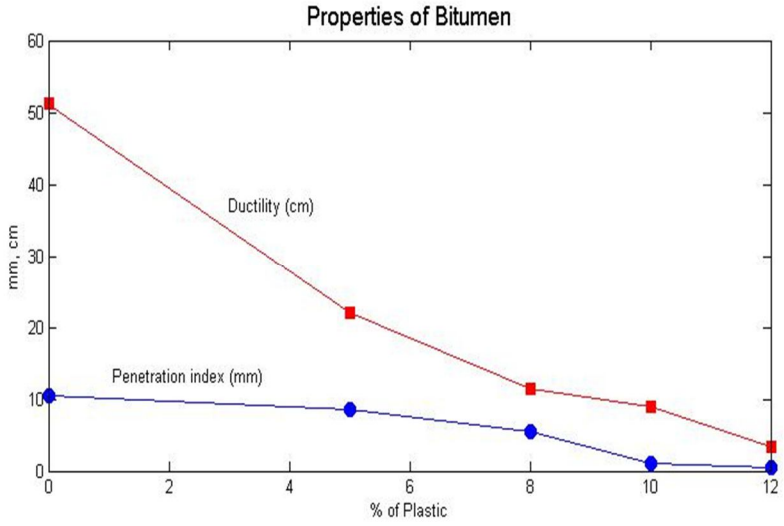

Fig 6 Variation of Ductility, Penetration with % of plastic replaced

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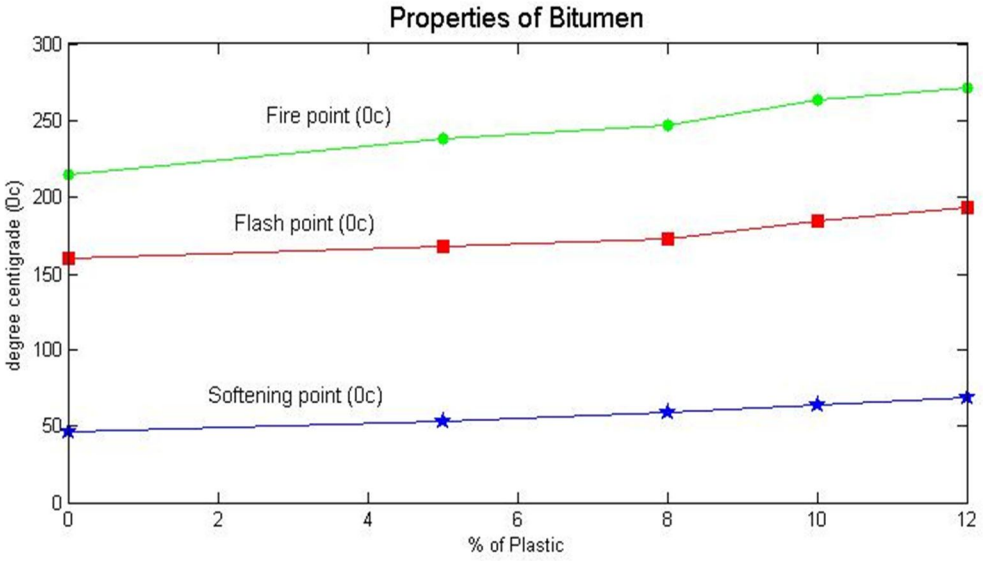

Fig 7 Variation of Fire point, Flash and softening points with % of plastic replaced.

A. Marshall Stability of SDBC in Wet Process

Table 3 Variation of Load and Displacement with % of Plastic (Wet Process)

S.No	% of Plastic	Load (KN)	Displacement (mm)
1	0	4.37	5.85
2	5	7.63	7.90
3	8	10.8	8.96
4	10	13.65	10.02

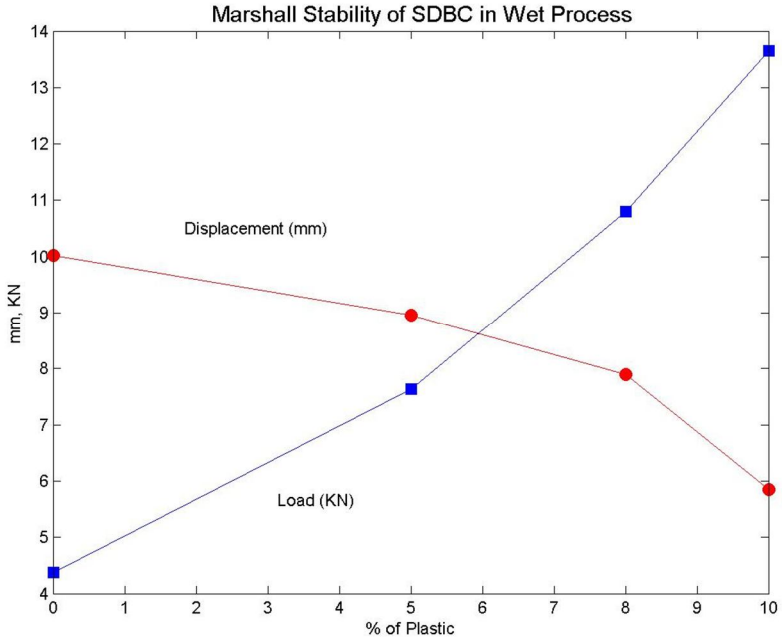

Fig. 8 Variation of Load and Displacement with % of Plastic (Wet Process)

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The experimental results of Marshall Stability test of SDBC in wet process was shown in table 5.2 and Fig 8. It is observed that the Marshall Stability value is increasing with an increasing plastic waste content i.e., the load is increasing with increase in % of plastic waste in bitumen.

B. Marshall Stability of SDBC in Dry Process

Table 4 Variation of Load and Displacement with % of Plastic (Dry Process)

S.No	% of Plastic	Load (KN)	Displacement (mm)
1	0	4.37	2.43
2	5	24.19	2.59
3	8	26.59	3.43
4	10	28.38	4.02
5	12	34.69	4.69
6	15	29.37	3.83
7	18	20.70	2.74

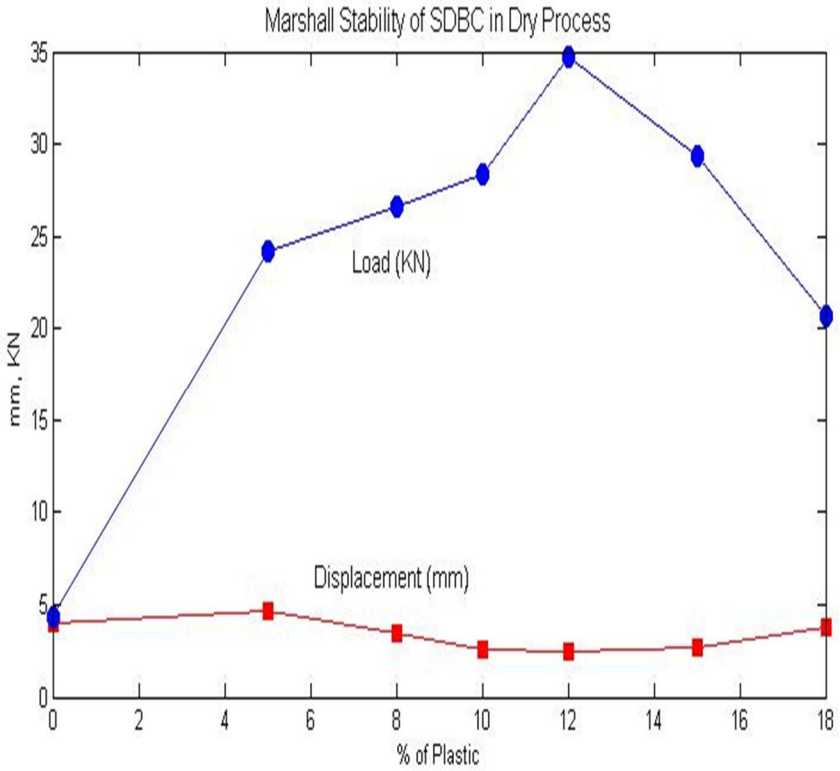

Fig. 9 Variation of Load and Displacement with % of Plastic (Dry Process)

From the experimental results as shown in Fig.9, it is observed that the Marshall Stability value is increasing with an increasing plastic waste content.

VI. CONCLUSIONS

When we compare the dry and wet process it is most effective to use dry process why because in dry process we can use up to 15% of plastic waste and binding also more with aggregate, where as in wet process we can use only up to 10% beyond this we can't use because it requires much mechanical energy, and stability is average. Marshal stability values of dry process are much better than the wet process, so in practical situation Dry Process is more suitable.

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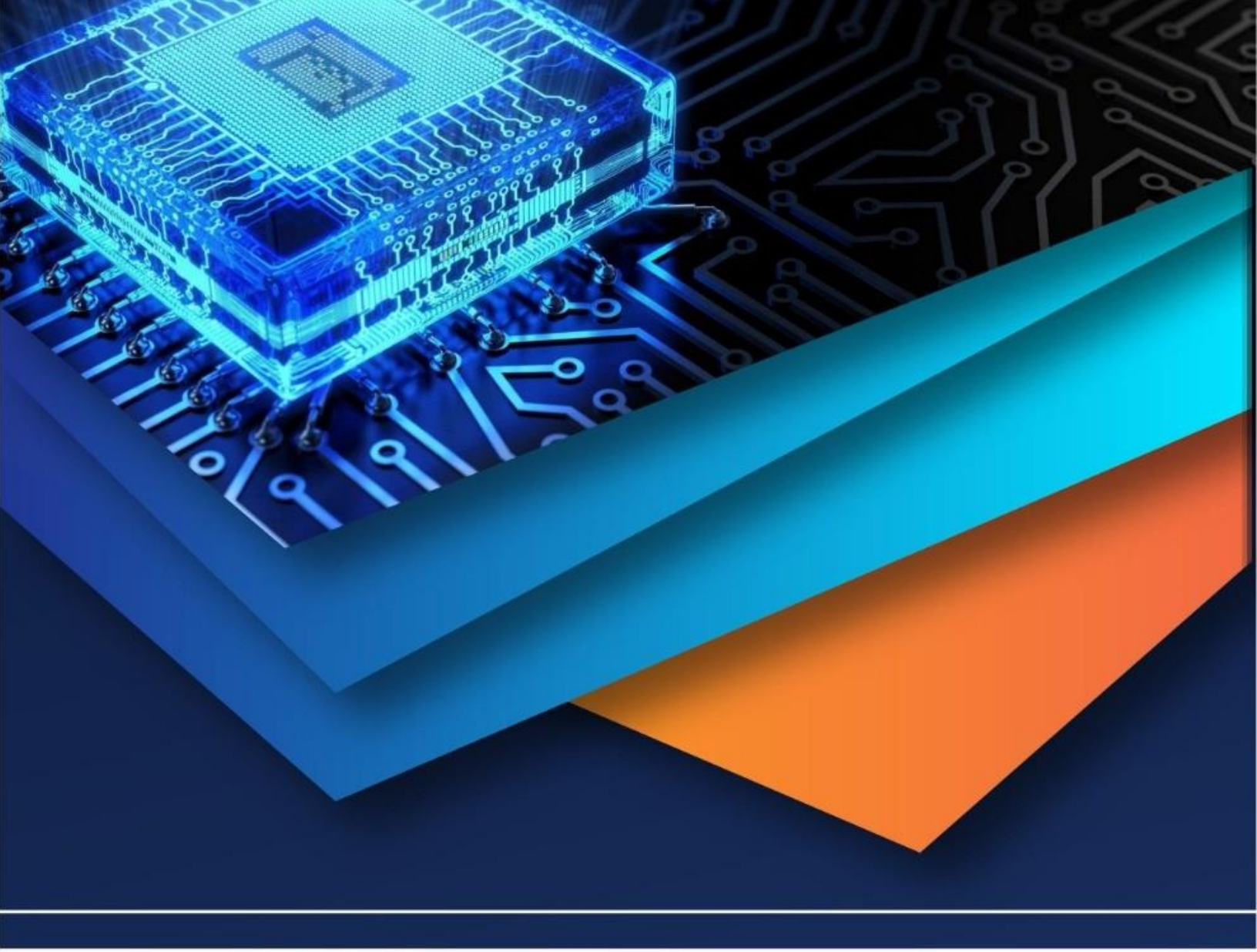

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