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Use of Plastic Waste as Partial Replacement of Bitumen for Repairing Potholes in Bituminous Pavement

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Abstract: The goal of this project is to see if plastic waste can be used to partially replace bitumen in the repair of potholes in bituminous pavement. The project's goal is to find out if using plastic waste improves bitumen's mechanical properties and whether it can be used as a sustainable alternative to traditional road construction materials. The review explores the mechanical properties of bitumen blended in with different rates of plastic waste, and the exhibition of the subsequent combination in fixing potholes. The findings indicate that plastic waste can be utilized as a partial substitute for bitumen, enhancing the bituminous pavement's durability, strength, and permeability. Bitumen made from plastic waste has the potential to cut down on pollution in the environment and make road construction and maintenance last longer.

The project involves testing the performance of the bitumen-plastic waste mixture in repairing potholes and carrying out experiments to ascertain the mechanical properties of the mixture. The project is expected to shed light on the possibility of using plastic waste as a sustainable alternative to bitumen for road construction and maintenance to help the construction industry develop more environmentally friendly and sustainable practices.

Index Terms: potholes, plastic waste, replacement.

I. INTRODUCTION

To provide connection and accessibility for people and products, roads and pavements are essential components of the transportation infrastructure. However, the development of potholes frequently jeopardises the toughness and lifespan of road surfaces, posing a risk to public safety, driving up maintenance costs, and aggravating other road users. The use of bitumen-based compounds, which are frequently employed in road building, is a part of traditional ways of patching potholes. The exploration of substitute materials, however, has been prompted by the negative environmental effects of bitumen, a petroleum-based product, and the rising concern over plastic pollution.

One such option is to partially replace the plastic used to patch potholes in bituminous pavement with bitumen. Bitumen in pavement repair applications can be partially replaced by plastic waste, which is a major environmental problem. By utilising plastic waste in a useful way, this strategy has the potential to both reduce the consumption of bitumen, a non-renewable resource and address the problem of plastic waste. A sustainable solution that could support the circular economy and lessen the environmental impact of road construction and maintenance is the use of plastic-modified bitumen for pothole filling.

In this research report, we'll look into the viability and efficacy of partially replacing plastic with bitumen for patching potholes in bituminous pavement. To compare the performance and durability of plastic-modified bitumen to conventional bitumen, we will conduct tests, examine the literature and studies on the subject, and examine the attributes of plastic-modified bitumen. The results of this study could advance knowledge and comprehension of environmentally friendly pavement repair techniques and their potential advantages in terms of lowering plastic waste generation and fostering environmentally friendly road construction and maintenance practices. We will examine the potential consequences and difficulties connected with the use of plastic-modified bitumen in pothole repair throughout the paper and give thorough analysis, data, and outcomes to support our conclusions. This report's material will add to the body of knowledge in the field of sustainable road building and offer guidance to professionals, decision-makers, and researchers looking for more eco-friendly methods of patching potholes in bituminous pavements.

The resistance of the rock is greater than the force exerted by the water and the sediment it carries. The eroded rock at that location continues after the process has begun. Furthermore, the passing occurring because of potholes or individuals getting harmed, still, isn't considered a significant and difficult issue. Due to potholes, approximately 3,597 people die annually. Potholes are the cause of more than 30% of deaths. According to figures provided by the Ministry of Road Transport and Highways, potholes have caused over 9300 deaths, 25000 injuries over the past three years, and 25,000 injuries currently. Despite this, India does not view it as a serious problem. Nevertheless, potholes are being created.

Consistently legislature of India spent crores in repayment and support of streets and to fill the potholes.

We have developed our project to address this issue because, as we are all aware, the management and disposal of waste plastic pose significant environmental risks. When roads are built with bitumen and plastic, not only do they last longer and run smoother, but they are also more cost-effective and better for the environment. Roads constructed with plastic waste are referred to as Plastic Roads and have been found to perform better than roads constructed with conventional bitumen. Bitumen is modified with plastic waste to improve some of its properties of the bitumen.

Our project focuses on incorporating plastic into the repair of potholes, particularly into the road's surface layer, where it can partially replace bitumen and make the road more durable and water-resistant to some extent.

Using more plastic waste cuts down the need for bitumen by 10%. Additionally, it improves the road's performance and strength. Plastic expands the dissolving point of bitumen and consequently missing should be possible in a better and simpler manner. Plastic waste, according to Dr R. Vasudevan, Dean ECA and Professor, Department of Chemistry, Thiagarajar College of Engineering, Madurai, replaces between 10 and 15 per cent of bitumen, saving between 35 000 and 45 000 rupees per kilometre of road. Consideration of plastic waste in street development kills the plastic shrinkage breaking of street surfaces and lessens the drying shrinkage somewhat.

A. Bitumen

VG30 grade bitumen is widely used for road construction, especially in countries with medium to high temperatures. VG30 stands for "Viscosity Grade 30," which refers to the viscosity of the bitumen at a given temperature (i.e., 60°C). This grade of bitumen is classified as a medium viscosity binder, with a typical penetration depth of 60-70 decimillimeters (dmm) and a softening point of about 50-60°C. VG30 bitumen is suitable for a wide range of road applications, including as a binder in hot mix asphalt (HMA), as a bonding agent for road pavements, and as a sealant for cracks and joints. It offers good durability, resistance to deformation and rutting, and excellent adhesion to aggregates. However, the suitability of VG30 bitumen for a particular road project depends on a number of factors, such as climatic conditions, traffic levels and the properties of the aggregates used. It is important to consider these factors carefully and to follow the relevant standards and guidelines for bitumen selection and mix design to achieve the best possible result.

B. Properties of bitumen

1) *Viscosity:* VG30 bitumen has a viscosity of 2400-3600 poise at 60°C. This property is important because it affects the flow of the bitumen during mixing and compaction.
2) *Penetration:* VG30 bitumen has a penetration value of 60-70 dmm at 25°C. This property indicates the hardness or softness of the bitumen.
3) *Softening Point:* VG30 bitumen has a softening point of 50-60°C. This property indicates the temperature at which the bitumen softens and begins to flow.
4) *Ductility:* VG30 bitumen has a ductility value of 100 cm at 25°C. This property measures the ability of the bitumen to stretch without breaking.
5) *Flash Point:* VG30 bitumen has a flash point of approximately 250°C. This property indicates the temperature at which the bitumen ignites when exposed to a flame.

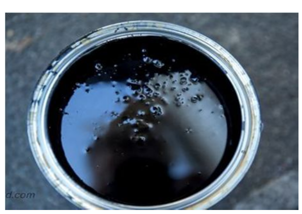

Fig - 1 : Plastic

Plastic is a ubiquitous and versatile material that has become an integral part of our daily lives. It is a synthetic material made from polymers, which are large molecules composed of repeating units called monomers. The invention of plastic in the mid-19th century revolutionized various industries and has since transformed the way we live, work, and consume.

The production of plastic has grown exponentially over the years, with billions of tons of plastic being produced annually worldwide. Plastic has found widespread use in various applications, such as packaging, automotive, construction, electronics, healthcare, and more, due to its durability, flexibility, and affordability. It has enabled advancements in areas such as transportation, food preservation, medical devices, and communication, among others, bringing significant benefits to society.

However, the widespread use of plastic has also led to environmental challenges. Plastic pollution has become a global concern, with plastic waste accumulating in landfills, oceans, and natural habitats, causing harm to wildlife, marine ecosystems, and human health. The persistence of plastic in the environment for hundreds of years and the challenges associated with plastic waste management have raised concerns about its sustainability.

Efforts are being made worldwide to address the environmental impacts of plastic, including recycling and waste management initiatives, the development of sustainable plastic alternatives, and policy interventions to reduce plastic pollution. Finding solutions to minimize the negative impacts of plastic while maximizing its benefits is a critical challenge for society as we strive for a more sustainable future.

It is estimated that approximately 10 thousand tons per day (TPD) of plastics waste is generated i.e. 9% of 1.20 lacs TPD of MSW in India. The plastic waste constitutes two major categories of plastics; (i) Thermoplastics and (ii) Thermoset plastics. Thermoplastics, constitutes 80% and thermoset constitutes approximately 20% of total postconsumer plastics waste generated in India.The Thermoplastics are recyclable plastics which include; Polyethylene Terephthalate (PET), Low Density Poly Ethylene (LDPE), Poly Vinyl Chloride(PVC), High Density Poly Ethylene (HDPE), Polypropylene(PP), Polystyrene (PS) etc. However, thermoset plastics contains alkyl, epoxy, ester, melamine formaldehyde, phenolic formaldehyde, silicon, urea formaldehyde, polyurethane, metalized and multilayer plastics etc. The use of plastic materials such as carry bags, cups, etc. is constantly increasing**.**

Fig -2: Aggregate

An aggregate of size 6.3 mm is still generally considered a fine aggregate rather than a coarse aggregate and is normally used for the finer layers of a bituminous road construction, e.g. for the leveling and binder layer.

For the surface course of a bituminous road, a coarse aggregate is usually used, ranging from 5 to 14 mm in size. This coarse aggregate provides structural support to the road and improves its durability, while providing good interlocking and void filling, ensuring proper compaction and reducing the risk of deformation and rutting.

The most commonly used coarse aggregates for the surface course of bituminous roads are crushed stone, gravel and slag. The aggregate should be hard, durable, and able to withstand the stresses of heavy traffic. In addition, the aggregate should be clean, free from dust and other impurities, and meet the appropriate specifications for size, shape, texture and gradation.

In addition to the physical properties of the coarse aggregate, its chemical properties are also important. The aggregate should be chemically stable and not react with the bitumen, as this can lead to premature failure of the road.

Overall, the selection and use of a suitable coarse aggregate is critical to the performance and durability of bituminous roads. It is important to follow the relevant standards and guidelines for aggregate selection and mix design to achieve the best possible results.

Fig – 3 :Aggregate

II. REVIEW OF RESEARCH PAPER

Apurva j Chavan work investigates the feasibility of using plastic waste in the construction of flexible pavements. The study examines the mechanical properties of asphalt mixtures containing different proportions of plastic waste and evaluates the possible advantages and disadvantages of using plastic waste in road construction.

The study found that the addition of plastic waste to asphalt mixtures can improve the mechanical properties of the mixtures, such as increased stability, stiffness, and resistance to deformation. The study also found that the use of plastic waste in asphalt mixtures can reduce the amount of bitumen required, which can lead to cost savings and a lower carbon footprint.

However, the study also identified some challenges and limitations associated with the use of plastic waste in road construction. These include the need to carefully control the amount and type of plastic waste added to the mix to avoid negative impacts on mix performance, the potential for harmful chemicals from the plastic waste to enter the environment, and the potential for reduced skid resistance due to the smooth surface of the plastic particles.

The paper concludes that the use of waste plastics in asphalt mixes for road construction is a promising approach that can offer several potential benefits. However, further research and testing is needed to fully understand the performance and environmental impact of this approach and to develop guidelines and standards for its use in practice.

Ahmad Zafar Merzakhill and Jagdeep Singh's research examines the durability of pothole repair using waste materials. The study examines the performance of pothole repair materials made from waste materials such as plastic, rubber and glass and evaluates their durability over time.

The study found that the use of waste materials in pothole repair offers several benefits, including reduced environmental impact, cost savings, and better performance compared to traditional materials such as hot mix asphalt. The study also found that pothole repair materials made from waste materials can maintain their structural integrity and withstand traffic loading for extended periods of time.

However, the study also identified some challenges and limitations associated with the use of waste materials in pothole rehabilitation. These include the need to carefully select and process waste materials to ensure their compatibility with the pothole repair process, the potential for reduced skid resistance due to the smooth surface of some waste materials, and the need for proper quality control and maintenance to ensure the long-term durability of the repairs.

The paper concludes that the use of waste materials in pothole repair is a promising approach that may offer several potential benefits. However, further research and testing is needed to fully understand the performance and environmental impact of this approach and to develop guidelines and standards for its use in practice.

Anupam Sharma and Nitin Dutt Sharma,The research paper titled "Utilization of Waste Plastic in Flexible Pavement" by Anupam Sharma and Nitin Dutt Sharma aims to explore the feasibility of using waste plastic as a partial replacement for bitumen in flexible pavement construction.

The paper begins by discussing the problem of plastic waste accumulation and its adverse effects on the environment. It then highlights the potential benefits of using waste plastic in road construction, such as reduced cost, improved pavement performance, and eco-friendliness.

The authors then describe the methodology used in their study, which involves adding shredded plastic waste in varying proportions (2%, 4%, and 6% by weight of bitumen) to bitumen and testing the resulting mixtures for various properties such as viscosity, penetration, and softening point.

The paper goes on to describe the results of the study, which indicate that the addition of waste plastic to bitumen can improve its performance in terms of stiffness, stability, and durability. The authors conclude that the use of waste plastic in flexible pavement construction is a viable option that can help reduce plastic waste while also improving the quality and sustainability of road infrastructure.

Huda shafiq study titled "Plastic Roads: An As of late Progression in Squander The executives" by Huda Shafiq expects to investigate the idea of involving plastic waste in street development, normally known as plastic streets, for the purpose of resolving the issue of plastic waste gathering.

The paper starts by examining the issue of plastic waste and its destructive consequences for the climate. Then, it talks about the possible advantages of using plastic waste to build roads, like less plastic waste, better road durability, and cheaper construction.

The author then talks about her study's methodology, which included reading and evaluating previous research on plastic roads and how they perform in different parts of the world.

The paper proceeds to portray the consequences of the review, which demonstrate that plastic streets can possibly resolve the issue of plastic waste and further develop street execution. The creator takes note of that the utilization of plastic waste in street development is a generally new idea and requires further innovative work to improve its viability.

In order to develop and implement plastic roads on a larger scale, the paper emphasizes the need for collaboration between the waste management and road construction industries. The creator likewise features the significance of public mindfulness and support in squander decrease endeavors to guarantee the outcome of plastic streets and other waste administration drives.

In general, the research paper highlights the need for additional research and collaboration in this field to maximize the utilization of plastic waste in road construction and provides valuable insights into the potential of plastic roads as a means of addressing the problem of plastic waste.

R. Manjuy, Sathya S., and Sheema K.'s study, "Use of Plastic in Bituminous Pavement," aims to determine whether waste plastic can be used as a partial substitute for bitumen in the construction of bituminous pavement.

The environmental harm caused by plastic waste accumulation is the subject of the paper's opening discussion. Then, it talks about the potential advantages of using waste plastic to build roads, like making the pavement work better, saving money, and being better for the environment.

The creators then, at that point, portray the philosophy utilized in their review, which includes adding destroyed plastic waste in changing extents (2%, 4%, 6%, and 8% by weight of bitumen) to bitumen and testing the subsequent combinations for different properties like entrance, mellowing point, and Marshall dependability.

The study's findings, which show that bitumen's stability, strength, and deformation resistance can be enhanced by adding waste plastic, are further discussed in the paper. The creators presume that the utilization of waste plastic in bituminous asphalt development is a reasonable choice that can assist with lessening plastic waste while likewise working on the quality and supportability of street framework.

In general, the research paper highlights the need for additional research and development in this field to maximize the utilization of waste plastic in pavement design and provides valuable insights into the potential benefits of using waste plastic in the construction of bituminous pavements.

Kashak Jambulkar, Pratik Badwaik, Sourav Singh, and Prajakta Wanjari's research paper, "Patching Work of Road Using Plastic Waste," aims to investigate the viability of patching roads with plastic waste.

The environmental harm caused by plastic waste accumulation is the subject of the paper's opening discussion. Then, it talks about the possible advantages of using plastic waste to build roads, like less plastic waste, cheaper construction costs, and better road durability.

The study's methodology is then explained, which involves testing mixtures for various properties like Marshall stability, flow value, and indirect tensile strength by adding shredded plastic waste to bitumen emulsion in varying proportions (0%, 1%, 2%, and 3% by weight of aggregate).

The study's findings, which show that adding plastic waste to bitumen emulsion can improve its stability and strength, are then described in detail in the paper. The authors come to the conclusion that patching roads with plastic waste is a viable option that can help reduce plastic waste while also improving road infrastructure quality and sustainability.

In general, the research paper highlights the need for additional research and development in this field to maximize the utilization of plastic waste in road construction and provides valuable insights into the potential benefits of using plastic waste in road patching projects.

III. TEST

A. Test On Aggregate

The following test were conducted on aggregate:

Impact value test (IS Code 2386 (part IV) -1963)

The impact value test is a typical method for determining the toughness or resistance to the impact of an aggregate, which is a granular material used in construction such as gravel, sand, or crushed stone.

Crushing test test (IS Code 2386 (part IV) -1963)

The crushing value test is a standard test used to evaluate the strength and durability of aggregates

Abrasion test (IS Code 2386 (part IV)-1963)

The abrasion test on aggregate is a typical method for evaluating aggregate durability and resistance to wear and tear.

Water absorption test (IS Code 2386 (part IV)-1963)

The water absorption test is a typical method for determining how much water an aggregate material can absorb.

Table - 1 :Test results of aggregate

Sr.no	Test	Property determined	Result
1	Impact value test	Toughness	9.1%
2	Crushing test	Crushing	16.25%
3	Los angeles test	Abrasion	22.20%
4	Water absorption test	Water absorption	2.55%

B. Test on Bitumen

The following teest were conducted on bitumen:
Penetration test (IS Code 1203 – 1978)
The penetration test is a popular method for determining the consistency of bitumen
Ductility test (IS Code 1208- 1978)
The test examines bitumen's capacity to stretch and distort without breaking
Flash and firepoint test(IS Code 1208-1978)
The flash point and fire point are two important properties of bitumen that relate to its potential to ignite and burn.

Table - 2 :Test results of Bitumen

Sr no	Test	Property	Result
1	Penetration test	Hardness	58 mm
2	Ductility test	Streching	72 cm
3	Flash and fire ponit est	Temperature	314.76 ℃ & 319.33℃

IV. CALCULATION

Bitumen and aggregate ratio mix
As per Nagpur Municipal Corporation specified:
For 9000 kg aggregate , 350 kg of bitumen required.
So, for 26 kg aggregate , 1 kg bitumen will be required
Ratio of Bitumen and aggregate mix
Bitumen : aggregate = 1:26 .
Ex : Sample weight =15 kg
Total = 1+26=27
Bitumen = 1/27 *15 =0.556 kg
Aggregate = 26/27*15=14.44 kg
For 5% of replacement of bitumen with waste plastic:
i.e. 5 % of 0.556 kg =28g
For 28 g of plastic will be added

14.44 kg = 556 g
(aggregate) (bitumen)
X = 28 g (plastic)
X = 28*14440/556 = 730 g

So, 730 g of aggregates added.
Similarly, if bitumen is 10% replaced with waste plastic.
Amount of plastic added =55.60 g
Amount of aggregate added=1444 g
Similarly, if bitumen is 15% replaced with waste plastic.
Amount of plastic added = 83.4g
Amount of aggregate added =2166 g

V. RESULTS

A. Percolation Test

Every sample for this test included 2 liters of water

Percolation Test				
Sr.No	Number of Samples	Time for percolation	Amount of water percolated	% of water loss
Sample without inclusion of waste plastic				
1	Sample A	2.22	1500	33%
Sample with addition of 5% waste plastic				
1	Sample 1.1	3.01	1400	30%
2	Sample 1.2	3.37	1500	25%
3	Sample 1.3	3.11	1550	22.5%
Mean	Sample B	3.16	1483	25.8%
Sample with addition of 10% waste plastic				
1	Sample 1.1	2.57	1100	45%
2	Sample 1.2	2.26	1250	37.5%
3	Sample 1.3	2.05	1400	30%
Mean	Sample C	2.29	1250	37.5%
Sample with addition of 15% waste plastic				
1	Sample 3.1	3.02	1700	15%
2	Sample 3.2	2.50	1700	15%
3	Sample 3.3	3.10	1600	20%
Mean	Sample D	2.87	1666	16.66%

In sample A, which is without inclusion of plastic taking time for percolation of 2.22 min and 1.5 litres of water is percolated through the voids present in the sample .
In sample B, in which 5% waste plastic (LDPE) is added into the bituminous mixtue taking average time for percolation 3.16 min & 1.483 litres of water percolated through voids.
In sample C, in which 10% waste plastic (LDPE) is added into the bituminous mixtue taking average time for percolation 2.29min & 1.25 litres of water percolated through voids.
In sample D, in which 15% waste plastic (LDPE) is added into the bituminous mixtue taking average time for percolation 2.87 min & 1.66 litres of water percolated through voids.
From above results we can say that in sample B percolation time is more compare to other samples i.e 3.16 minutes which means number of voids must be less than the other sample.

B. Resistance To Crack Formation Test

By using univeral testing machine (UTM)

Sr. No.	Specimen Type	Load at failure (KN)	Deflection amount (mm)
1	Without Plastic	5.55 KN	18.3mm
2	With 5% Plastic addition		
	Sample 1.1	5.89 KN	10 mm
	Sample 1.2	5.83 KN	10.3 mm
	Sample 1.3	5.87 KN	10.1 mm
Mean		5.86 KN	10.13 mm
3	With 10 % Plastic addition		
	Sample 2.1	5.79 KN	7.5 mm
	Sample 2.2	5.77 KN	7.2 mm
	Sample 2.3	5.78 KN	7.6 mm
Mean		5.78 KN	7.43 mm
4	15 % Plastic addition		
	Sample 3.1	5.54 KN	14.2 mm
	Sample 3.2	5.55 KN	14.3 mm
	Sample 3.3	5.53 KN	13.9 mm
Mean		5.54 KN	14.13 mm

In sample without plastic mix , the load required for failure is 5.5 KN and deflection occur was 18.3 mm.
The sample of 5% added plastic the load required for crack formation was around 5.89 KN and deflection was 10 mm.
In a sample of 10% added plastic the load required for crack formation was around 5.79 KN and deflection was 7.5 mm.
In the sample of 15% added plastic the load required for crack formation was around 5.54 KN and the deflection occur was 14.2 mm. After the comparative study of these result we conclude that resistance against crack formation in waste plastic bituminous mix at 5% is more than other 10%,15% of plastic added mix and also without mixed plastic specimen.
From the above readings , we conclude that the resistance against the crack formation in waste plastic bituminous mix at 5 % is more than the normal bituminous mix .

VI. CONCLUSION

After comparative study, It has been discovered that replacing 5% of waste plastic with bitumen mix has promising results in terms of porosity, melting point, and crack formation resistance.
To achieve the desired properties like less porosity, high melting point, durability and resistance to deformation 5% of waste plastic should be add in the bituminous mixture.
In the economic point of view, the bitumen partially replaced by waste plastic saves money.

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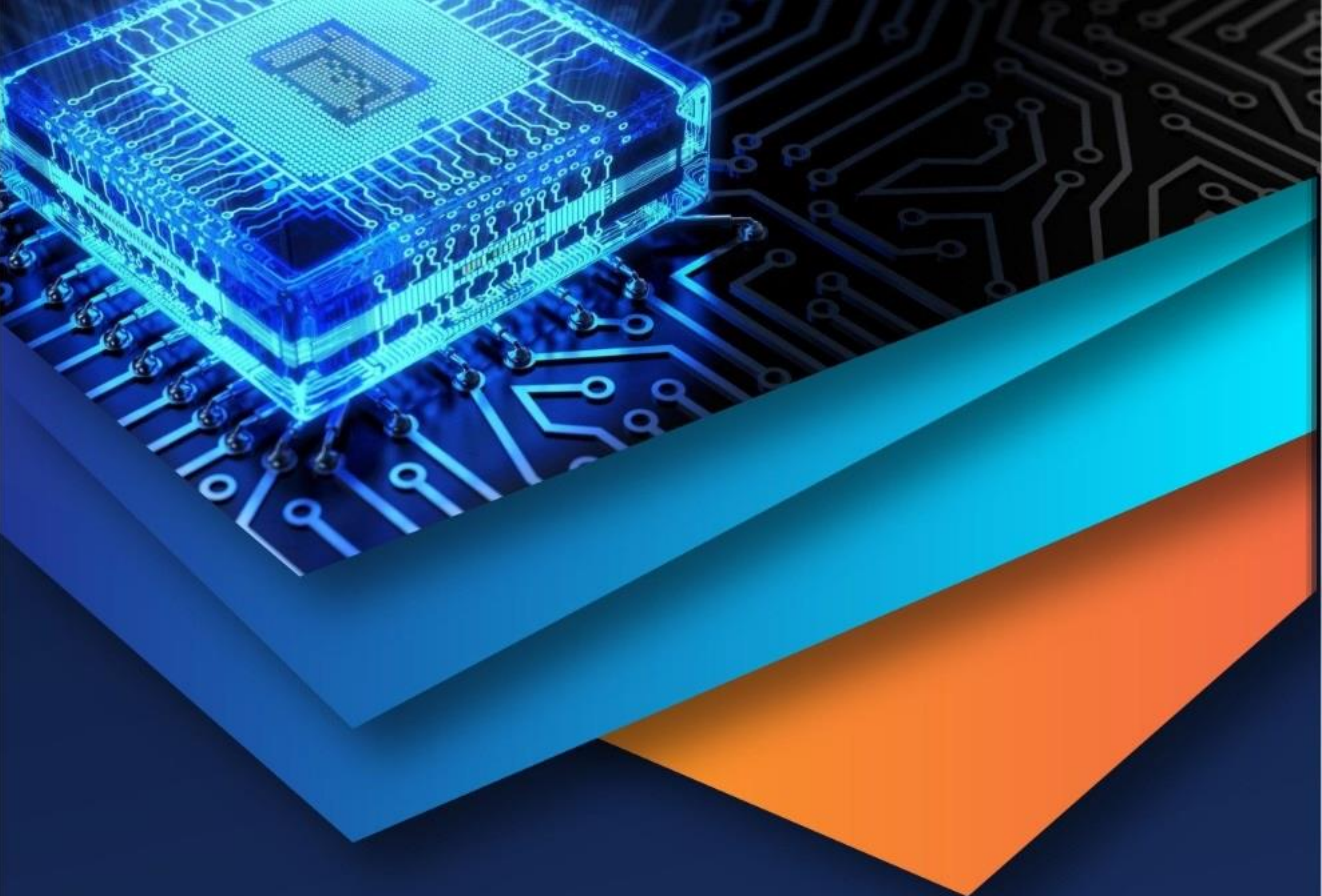

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