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An Experimental Study on a Flexible Perpetual Pavement - A Pavement with Durable Life

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Abstract: ***This Paper is related on an Experimental Study on "Flexible Perpetual Pavement and its durability nature (PP) through material replacements advancements and plastic adhesive utilizations in the structural design of perpetual pavement". As the Indian Road network is the second largest road network in the world, so usage of innovative materials, automation, and machine control technologies in the road construction sector is been encouraging. Sustainability of road construction is one of the important factors of, social development economy in future. Several research projects are currently in way to study different construction methodologies, materials and designs that can improve the sustainability of roads. So, considering all these aspects, perpetual pavement is a mechanistic designed asphalt pavement that could be built to diffuse the vertical strain and horizontal strains of road of traffic loading by its physical properties which gives a long durable life. So, this paper mainly serves on replacement technologies in various layers of perpetual pavement structural design and adding's of plastic fine materials, which can save on materials and reduction of crust thickness which will effect on construction and reduces the maintenance activities along with pavement lifetime and improve in sustainability.***

Keywords: Durability, HMA-Hot Mix Asphalt, PP-Perpetual Pavement, Replacement advancements, Plastic Fines, Vertical and Horizontal strains and Traffic load.

I. INTRODUCTION

Perpetual pavement is a bituminous pavement designed and built to long lasting for more than five decades without requiring any major structural rehabilitation or reconstruction. The potential nature of fatigue cracking is reduced, and the pavement distress is typically confined to the upper layer of the structure. Thus, when surface distress reaches a critical level, only replace the top layer. The perpetual pavement concept can be used for any pavement structure where it is desirable to the New Green field access controlled or semi access controlled brown field high embankment expressways to minimize rehabilitation and reconstruction costs. Bituminous pavements have been designed for a 20-year life, whereas perpetual pavements are expected to perform for 40 years or more. Through an alternative pavement design methodology, it is possible to obtain optimal bituminous pavement structures that will last for 40 years or more required only a wearing surface relay. Such design methodology should include mechanistic pavement design, replacement of materials/innovative design considerations to improve durability and fatigue resistance, and life-cycle cost.

II. OBJECTIVE OF THE STUDY

The Main objective of this paper is to study and discuss on "Flexible Perpetual Pavement and its durability nature through some alternative design considerations in its physical properties" and evaluate with some observations on the Perpetual Pavement Structure Design. The Study Concludes with the observations during the study and Need of the Perpetual pavement to the Indian Roads. Samples used in the study have been collected from various places in districts of Tamilnadu.

III. LITERATURE REVIEW

A. General Concept of the perpetual pavement(pp)

The concept of Perpetual Pavement was defined on a mechanistic principle that thickly designed HMA pavements with the appropriate material combinations. The design philosophy is such that the pavement structure must: Have enough structural strength to resist structural distresses such as bottom-up fatigue cracking, permanent deformation, and rutting; and be durable enough to resist damage due to traffic forces. The design principle thus consists of providing enough stiffness in the upper pavement layers to prevent rutting and flexibility in the lowest HMA layer to avoid bottom-up fatigue cracking and make it as durable for long time life of pavement.

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Fig.1 Typical Structural Section of Perpetual Pavement stress and strain distribution (Source: Google)

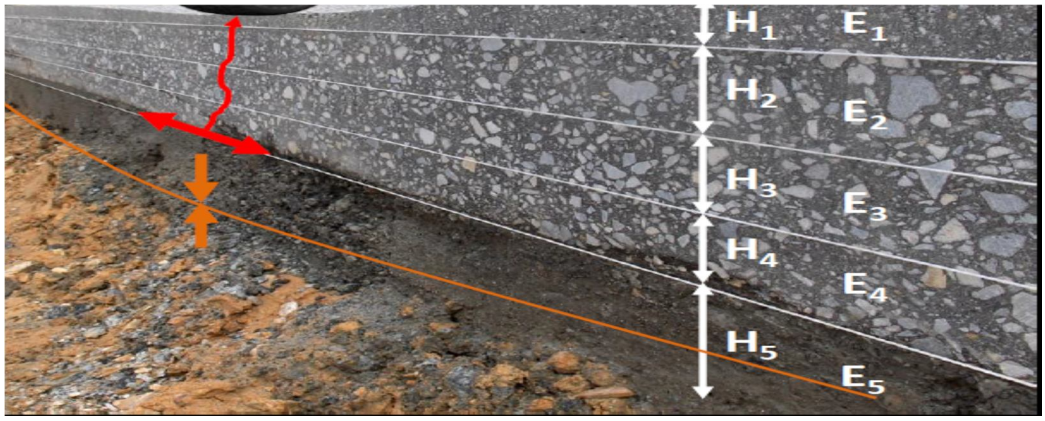

Fig.2 Typical Structural Section of Perpetual Pavement (Source: Google)

In general, the layer thicknesses varies depending upon the traffic load carrying factor and materials and/or mix-designs. However, the rut-resistant of intermediate layers are often the thickest element, providing sufficient load capacity.

B. Typical Design Concept of Perpetual Pavement

Perpetual pavement structure should have unique mechanical and physical characteristics to accomplish long term performance. The perpetual pavement sections should have a 40 to 50-year structural design life. The wearing course of a perpetual section should have a design to sustain about 20-year design life. The perpetual pavements layers are specifically designed to bear all the vertical and horizontal distresses occur through the top surface course layer. The perpetual pavement design theory limits the distresses to top-down cracking in the top bituminous lift which is designed as a high-quality, thin HMA layer. These are repaired to limit the pavement roughness, to increase skid resistance, to increase tire-pavement interaction and to reduce noise. The lower HMA layers are designed to resist fatigue cracking, rutting, and permanent deformation. The perpetual pavement design structural performance is a function of the traffic loads, speed, climate, subgrade and pavement parameters, materials, construction, pavement compaction and maintenance quality.

Construct the pavement over a sound subgrade if require Any stabilization techniques can be applied to enhance the structural stabilization of the subgrade. Next to the subgrade layer Fatigue resistant base layer to resist bottom-up fatigue cracking, which needs to be very flexible without any crack initiation passes through it to the top layer. And coming to rut resistance through Intermediate Layer is to be installed which should be responsible for the rutting deterioration. Followed with the repairable surface course to maintain the skid resistance.

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Base layer can be implemented by using a softer binder and higher binder content, which increases the bituminous flexibility and eliminates crack development when subjected to traffic loading. Bottom Mix, of these layers shall show the superior performance and resistance to fatigue cracking. In addition, the bottom mix layers reduce moisture susceptibility and enhance field compaction as it reduces in-place air voids in the field from7.0% to less than 6%. Next to the bottom mix layer the intermediate layer is designed as a rut resistant layer. This can be achieved through designing a stable and durable layer with the new Super pave design methodology. The stability of bituminous mix is a result of stone-on-stone contact. Thus, this layer is characterized by large nominal maximum size adding internal friction to the mix. An appropriate high temperature grade of bituminous binder is the factor which enhances the durability of the bituminous mix. The high temperature grade should be that of a surface grade to alleviate structural rutting. The wearing surface layer is designed to withstand traffic and environmental conditions. It should be rut-resistant layer and eliminate surface cracking while providing a reliable surface drainage to prevent splash and spray. The surface course is usually designed as a dense-graded Super pave mix, Stone Matrix Asphalt (SMA) and Open Graded Friction Course (OGFC). Where at the same time SMA and OGFC are expecting to result in better long-term performance result.

IV. EXPERIMENTAL STUDY-I

A. Experimental Utilization of RAP Material in Sub Base Courses of Perpetual Pavement

Reclaimed Asphalt Pavement (RAP) is used as an alternative of fresh or virgin aggregates word. In India and other developing countries sufficient standards and guidelines as well efficient procedures are not available to characterize the reclaimed asphalt materials. Now it is highly required to classify the available RAP materials for further use in road construction. Reuse of these materials can reduce 25% to 30% cost of highway projects. Reclaimed Asphalt Pavement (RAP) materials can be characterize by different ways, such as sources of RAP, gradation characteristics of RAP, physical and chemical properties of RAP aggregates, recovered bitumen percentage and properties of recovered bitumen etc. In this study the observations are conducted to characterize the RAP material on the basis of its Origin or Source. The RAP is a deteriorated bituminous mix that contains aged bitumen and aggregates.

Upon selected RAP and Virgin aggregates to explore the feasibility of producing high-performance granular base/sub base layers that contain up to 30 and 35% RAP material. The main objective of the study is also find out suitability of Reclaimed asphalt pavement (RAP) materials to be used in construction of Flexible Perpetual pavements. This study was conducted to classify the RAP from Surface Recycling. RAP material obtained from different types of deteriorated bituminous pavement can be broadly classified as given in table.

Fig.3 Core and Crushed Sample with RAP material

IS Sieve(mm)	Percentage passing by weight	Requirement for GSB grading II (table 400-2) of MORTH revision 4
53	100	100
26.5	92	50-80
19	80	-
10	66	-
4.75	38	15-35
2.36	22	-
0.6	11	-
0.075	2	<10

Table: I Particle size distribution for reclaimed asphalt pavement (RAP)

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Type of Property	RAP Property	Typical Range of Values
Physical Properties	Unit Weight	1940 - 2300 kg/m^3 (120-140 lb./ft^3)
	Moisture Content	Normal: up to 5% Maximum: 7-8%
	Asphalt Penetration	Normal: 10-80 at 25°C (77°F)
	Asphalt Content	Normal: 4.5-6% Maximum Range: 3-7%
	Absolute Viscosity or Recovered Asphalt Cement	Normal: 4,000 - 25,000 poises at 60°C (140°F)
Mechanical Properties	Compacted Unit Weight	1600 - 2000 kg/m^3 (100-125 lb./ft^3)
	California Bearing Ratio (CBR)	100% RAP: 20-25% 40% RAP and 60% Natural Aggregate: 150% or higher

Table: II Physical and Mechanical properties of (RAP)

Property of Aggregate	Type of Test	Test Method
Crushing strength	Crushing test	IS : 2386 (part 4)
Hardness	Los Angeles abrasion test	IS : 2386 (Part 5)
Toughness	Aggregate impact test	IS : 2386 (Part 4)
Shape factors	Shape test	IS : 2386 (Part 1)
Specific gravity and porosity	Specific gravity test and water absorption test	IS : 2386 (Part 3)

Table: III Tests on Aggregates with IS codes

IS Sieve size (mm)	Material			Percent				Requirement for GSB grading II (table 400-2) of MORTH revision 4
	40 mm down	RAP	Stone dust	60% 40 mm down	30% RAP	10% Stone dust	Total	
53	100	100	100	60	30	10	100	100
26.5	65	95	100	39	28.5	10	77.5	50-80
4.75	8	30	97	4.8	9	9	23.5	15-35
0.075	1	3	7	0.6	0.9	0.8	2.2	<10

Table: IV Sieve Analysis Details of composite Granular Sub Base with use of RAP

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IS Sieve size (mm)	Material				Percent					Requirement for WMM grading (table 400-II) of MORTH revision 4
	45 mm down	RAP	11.2 mm down	Stone dust	32% 45mm down	35% RAP	13% 11.2 mm down	20% Stone dust	Total	
53	100	100	100	100	34	36	11	19	100	100
45	100	100	100	100	34	36	11	19	100	95-100
20	25	80	100	100	8.5	28.8	11	19	67.3	60-80
12.5	0	63	94	100	0	22.68	10.34	19	52.02	40-60
4.75	0	40	5	98	0	14.4	0.55	18.62	33.57	25-40
2.36	0	19	0	88	0	6.84	0	16.72	23.56	15-30
0.6	0	15	0	34	0	5.4	0	6.46	11.86	8-22
0.75	0	3	0	10	0	1.08	0	1.9	2.98	<10

Table: V Sieve Analysis Details of composite Wet Mix Macadam with use of RAP

Characteristics	100% RAP Aggregates	100% Natural Aggregates	MORTH Limits (Max.)
Aggregate Crushing Value	23.2%	20.01%	30%
Aggregate Impact Value(AIV)	21.6%	18.3%	30%
Flakiness & Elongation Index(FI & EI)	23.2%	18.9%	35%
Loss Angeles Abrasion Test Value	19.6%	16.1%	30%
Specific Gravity	2.7	2.8	2.6-3.0
Water Absorption	1.7%	1.38%	2%
Soundness Test	8.0	5.8	12

Table: VI Results on Samples between 100% of RAP and 100% Virgin Aggregate

B. Observations from the Study

The result was obtained on combination of 30% RAP along with 60% of Virgin Material in GSB and where as 32% of Virgin Material and 35% as RAP material which follows by stone dust etc.,

It was observed that RAP materials can be successfully used in granular sub base layer of Perpetual flexible pavements after blending to match the required grading as per MORTH specifications can reduce the thickness of top layer even with out any Structure/Surface distress due to the traffic flow.

V. EXPERIMENTAL STUDY-II

A. Utilization and Replacement of Fine Virgin Aggregates with Fine Plastic Materials in Perpetual Pavement

The main focus of the perpetual pavement concept is to eliminate bottom-up fatigue cracking. With this the replacement of fine virgin aggregate is made with plastic fines. The use of plastic fines may be through by non-reusable materials, which are not undergo for bio decomposition. Waste plastics - the majority of which is usually put into landfill, incinerated, or polluted into the environment. Landfilling and incinerating plastic are both problematic methods of managing plastic waste. Plastics in landfills can leak pollutants into the surrounding soil; incinerating creates gaseous pollutants, such as carbon dioxide. As per IRC SP 98 2013 Guidelines for the use of waste plastic in hot bituminous mixes(dry process) in wearing coats. Reuse of bulky wastes is considered the best environmental alternative for solving the problem of plastic disposal.

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The Objective of this experimental study is to study on effect of plastic in Hot Mix Asphalt. Along with the effect of different percentage of bitumen content in Hot Mix Asphalt and also to determine the optimum perpetual pavement structure using the design philosophy of IRC 37.

B. Material Used are As follows

1) Binder Material: Bitumen Grade: 60/70 carried out as 5.5% and 6.5% of total weight of sample for HMA.

Characteristics	Min Requirement
Penetration Value	66 mm
Softening Point	53 Degrees
Flash Point	173 Degrees
Fire Point	175 Degrees
Ductility	80 Cm
Softening Point	53 Degrees

Table: VII Results on Bitumen

2) Aggregate of Size Varying between 20mm – 4.75 mm with the following

Characteristics	Min Requirement
Specific Gravity	2.6
Water Absorption	0.9%
AIV	17.5%
Crushing Value	1.73%
Abrasion Value	16.38%

Table: VIII Physical Properties of Course Aggregate

C. Plastic Fines Replacement

Characteristics	Utilized
Specific Gravity	0.887
Percentage of Voids	32.1%
Fineness Modulus	4.787
Bulk Density	0.6 g/CC

Table: IX Physical Properties of Plastic Fines

All the aggregate gradation are been adopted as per the MoRT&H and IRC Specification the sample is been prepared with 1100 gms of virgin aggregates and d filler is heated to a temperature of 180-190 degrees along with heating of bitumen with 120-130 degrees Celsius. Mix has been mixed continuously at a heating temperature of 125 degrees Celsius and mix is placed in preheated moulds and compacted with rammer with 75 blows on either side. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-2 mm. The bitumen content is varied to 5% and 5.5% with followed trails. All the trails are done through the Marshal stability Test as Marshall mix design.

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D. Test Results on Specimen

Property	Result	Min Req
Binder Content	5.2%	5%
Plastic Fine material usage	7.5%	6%
Air Void Content %	3.78%	4% in Lab and 8% as Practically workables
Voids in CA %9(Dry)	28	30
Voids in Mineral Aggregate(%)	15	>17
Tensile Strength	80	80%

Table: X Results on Sample

E. Observations From the Experimental study

It was observed that when bitumen percent is increased stability and flow value is also increased and when the percent of bitumen is increasing then the value to V.F.B. is increasing for all gradation. V.F.B 15% Voids in Mineral aggregate and 3.78% air voids in the mix were fulfilled as HMA Mix design criteria. Tensile Strength Ratio is more so, it indicating improving the adhesion property of binder. With the minimum dosage Optimum dosage of Binder content i.e. plastic fines of 7.5 is found to be 5.2% by total weight of mix for 60/70 grade of Bitumen.

VI. ADVANTAGES OF PERPETUAL PAVEMENT

A. Some of the major benefits derived from perpetual pavements the following:

B. High structural capacity for high traffic volume and heavy truck loads Long life and low life-cycle costs with minimal or no major structural rehabilitation activities; and a competitive option to rigid pavements.

C. Because of the crust thickness of Perpetual Pavements cost of construction will be high compared to conventional method of laying Road still by alternative design methodologies and very low maintainace the cost will come down compared to conventional method of construction.

D. The above benefits will generally outweigh this effect, particularly in the long-term, thus providing a sustainable solution to the ever growing traffic for the highway agencies.

E. Surface layer is only resurfaced and the base layers of pavement structures remains same, there will saving in construction raw materials.

F. Also, the user-costs associated with construction delays are greatly reduced because routine maintenance can be done quickly in off-peak hours.

G. All these factors not only result in a more cost-effective design but also a reduction in the emission of gases.

H. By reducing gas emissions, Perpetual Pavements can mitigate climate change, both now and for generations to come.

VII. NEED OF PERPETUAL PAVEMENT WITH VARIOUS DESIGNS

India is attaining greater modernization, the number of vehicles on the road is increasing, this imposing the greater distress on the country's roads in the form of increased fatigue cracking and structural and surface rutting and directly increasing the maintenance cost and resource consumption. Pavements which are traditionally designed for 20 years need structural rehabilitation and reconstruction after their design life has been reached; this involves major traffic closures and rerouting adding to the rehabilitation cost. Perpetual Pavements have been found to improve this situation as they are capable of maintaining the pavement performance for nearly 50 years without requiring major structural rehabilitation, As only the surface is renewed and the base structure stays in place, there is considerable saving of construction materials, which makes the cost reduction of new formations and new constructions for further. Though the initial construction cost of perpetual pavements is higher than that of conventional pavement the benefit in constructing the perpetual pavement would be on the long term.

So, The benefits resulting from perpetual design with various emphasizes that sustainable roads and perpetual designs are counterparts.

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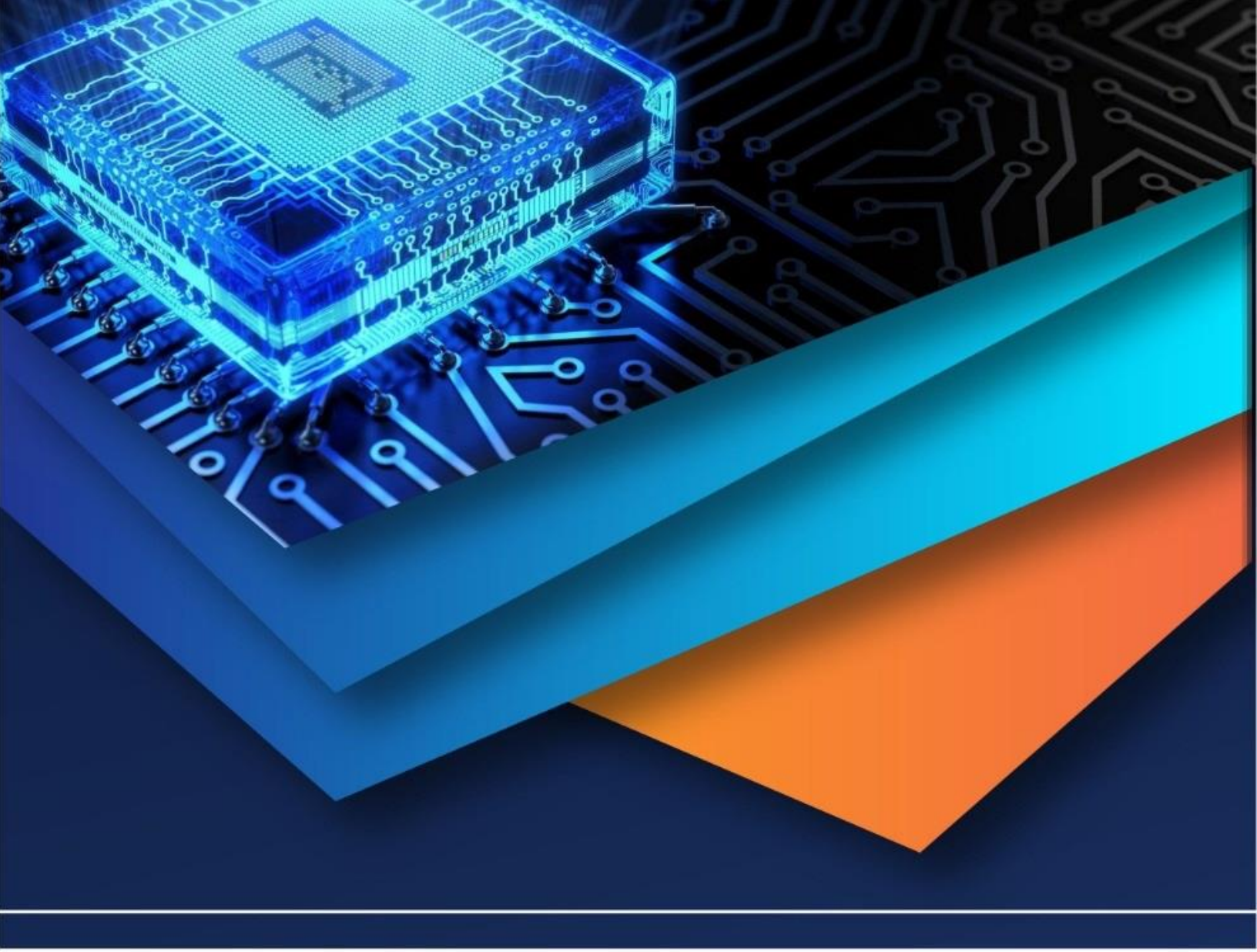

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