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Characterization of Nano Clay Modified Asphalt Cement

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Abstract: ***In order to enhance the service life of flexible pavements, asphalt binder must be modified. The aim of this research is to compare the physical and mechanical properties of virgin and Nano clay modified asphalt cement. These properties include viscosity values and rutting resistance. Nano clay were incorporated in asphalt binder in various percentages ranging from 3%, 3.5% to 5% of the asphalt weight. The viscosity (Cst) and rutting resistance of the modified asphalt binders were evaluated and compared to an unaltered binder. The addition of Nano clay as a modifier improved the asphalt's properties. The results of the study revealed an increase in viscosity and decrease in binder penetration. Consequently, the viscosity and rutting resistance of the modified asphalts increase with the increase in Nano clay content. While the viscosity and rutting resistance values decrease when the modifier content is increased to 5%. Hence the best improvements in the modified asphalt binders were obtained with 4.5% Nano clay content.***

Keywords: Organo philic clay, asphalt cement, Hamburg wheel tracker (HWTT), rutting, viscosity, rotational viscometer (RV).

I. INTRODUCTION

Increasing traffic loads and traffic volume, combined with the rising cost of asphalt, have led to an urgent need to improve the durability, safety and efficiency of asphalt pavements through asphalt modification. Temperature susceptibility characteristics and physical properties of asphalt binder at high and low field operating temperatures can affect the final performance of the mixture. To improve the performance of bitumen and asphalt concrete mixtures, the addition of modifiers such as Nano particles has become popular in recent years.

Polymeric Nano composites are one of the most exciting of materials discovered recently and the physical properties are successfully enhanced when a polymer is modified with small amounts of Nano clay, on the condition that the clay is dispersed at Nano scopic level [1]. Nano clay (NC) is one of the most affordable materials that have shown promising results. [2]. Because Nano clays are micro-scale fillers which would make polymers efficient as reinforcement, many researches showed that Nano clay modification can improve mechanical behaviour properties of mixtures such as indirect tensile strength, creep and fatigue resistance [3].

Nano clay is made from Montomorillonite (MMT) mineral deposits with average dimension of 1 nm thick and 70-150 nm wide. Nano clays are known to enhance properties of many polymers leading to better clarity, stiffness and thermal stability.

Also, in recent years there have been many interests in developing Nano clay reinforced composites due to their improved performance at high temperatures under various loading conditions including impact [4]. Soltani gave a detailed study concerning the engineering properties of Nano clay modified asphalt concrete mixtures [5]. The investigation showed that Nano clay can improve properties such as stability, resilient modulus and direct tensile strength. Superior performance under dynamic effect was noticed compared to that of unmodified bitumen under dynamic creep Also, the study showed that the optimum binder content and void in total mixture increased by adding Nano clay to bitumen. Lam showed that layered Montmorillonite (MMT) as a newly invented Nano filler can extraordinary improve the mechanical behaviours of polymer matrix [6]. Nano materials have at least one dimension measuring less than 10 nanometer (nm) at least. Due to their small size, usually Nano materials have the higher reactivity ability and special surface properties, which can be used for industry products. Due to the special properties of the above-mentioned, Nano materials, they are good candidates for implementation into asphalt pavements. In recent studies where Nano clay material was added to modify the base asphalt binder, it was found that Nano clay could increase the shear complex modulus and reduce the strain failure rate of base asphalt. Furthermore, the addition of Nano clay in the base asphalt binder could weaken the moisture susceptibility of asphalt mixture [7] Exploiting nanoparticles to improve the properties of bitumen and asphalts: at what extent is it really worth it [8].

Asphalt is usually employed as an organic binding material for waterproofing, moisture resistance and corrosion protection. Modification of base asphalt is required to improve the materials performance (e.g. adhesion, temperature sensitivity, friction properties, oxidation resistance, aging resistance and durability).

In recent years, nanotechnology has gradually been incorporated into the field of modified asphalt with various kinds of Nano materials being used to modify asphalt, Rheological properties of bitumen containing Nano clay and organic warm-mix asphalt additives [9].

Using Nano clay reduces the penetration grades, while it improves the softening point temperatures of the modified asphalts. The greater drop in the penetration value, correspondingly rise in the softening point are seen at 7% Nano clay proportion for all types of modified asphalts in compared with the original asphalt [10]. The G* values increased when the binder was modified with Nano clay, meaning higher stiffness of the modified asphalt binder. The phase angle of the modified asphalt lower than the raw asphalt means that the behaviour of the binder tended to be more elastic and less viscous [11].

II. PROBLEM STATEMENT

The viscosity of bitumen affects its workability and service life. The viscosity of bitumen directly affects the performance of asphalt binder. Modification of base asphalt is required to improve the material's performance (e.g. adhesion, temperature sensitivity, friction properties, oxidation resistance, aging resistance and durability). If viscosity is not controlled in a certain limit it may affect temperature sensitivity and durability of asphalt cement.

III.OBJECTIVES

The main objectives of this study are:

1) To find flow characteristics (viscosity) of Nano Clay modified asphalt cement.
2) To optimize the percentage of Nano clay in asphalt cement.
3) Evaluating the effects of Nano clay on performance behavior of asphalt cement.

IV.MATERIALS

A. Asphalt Cement

This study used two types of asphalt cement from a single source: NRL 60/70 and NRL 80/100 from the National Refinery Oil Limited. Following the ASTM standards, the basic physical parameters of the asphalt binders were quantified in table 1.

TABLE I
Physical Properties of Asphalt Cement

Properties	Standard Code	Unit	NRL 60/70	NRL 80/100	Specification Limit (minimum)
Penetration 0.1 mm @ 25°	ASTM D5	1/10 mm	60-70	80-100	80
Softening Point (°C)	ASTM D36	°C	46-57	43-54	43
Ductility at 25°C	ASTM D36	cm	100	100	100
Dynamic Viscosity	ASTM D4402	cP	340.2	356.3	300

B. Nano Material

Figure 1 show the nanomaterial employed in this study i.e. organo philic nano clay. Smectite clays, such as sodium bentonite, with moisture content of up to 10% are sprayed within an activator component that is ammonium sulphate, and mechanically compacted to make organo philic Nano clay.

Fig. 1 Organo Philic Nano Clay

V. METHODOLOGY

For all types of binders, three samples were prepared for each Nano clay content (3%, 3.5%, 4.0%, 4.5%, 5%) in order to conduct tests in accordance with ASTM D4402 [11] and AASHTO T324 [12] standards.

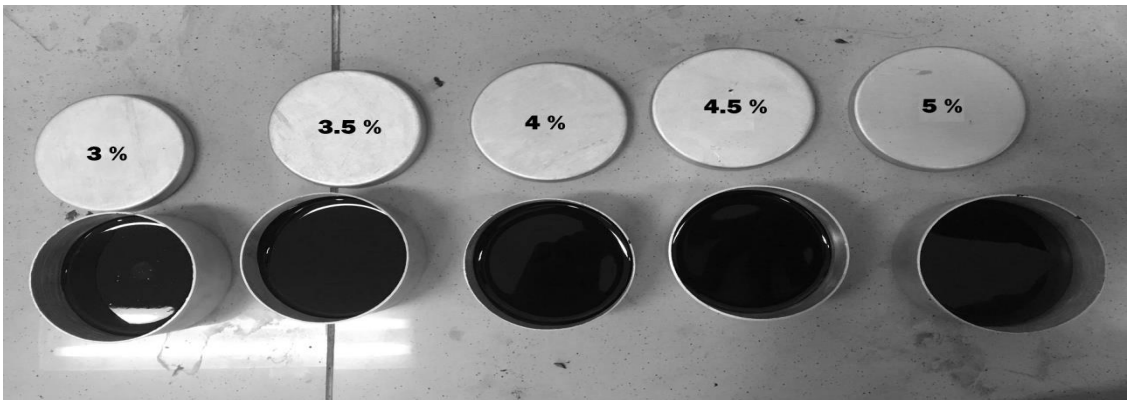

Fig. 2 MODIFIED ASPHALT CEMENT WITH DIFFERENT PERCENTAGES

A. Viscosity Test (ASTM D4402)

The asphalt cement is heated to 160°C until it melts and become fluid, and then a fraction of Nano clay is added to asphalt cement to ensure uniform dispersion of Nano clay paticles. The rotational viscometer is then used to assess the viscosity effects.

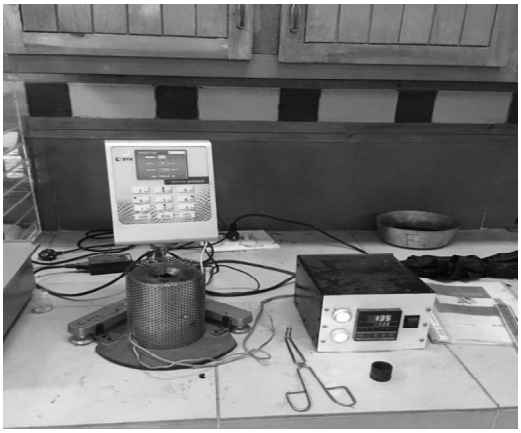

Fig. 3 EVALUATION OF VISCOSITY BY ROTATIONAL VISCOMETER

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B. Rut Performance (AASHTO T324)

Using Nano Clay modified bitumen, 5 moulds were prepared with clay content 3.0%, 3.5%, 4.0%, 4.5% and 5.0%. The moulds were compacted using Superpave Gyratory Compactor and then subjected to Wheel Tracker Test.

Fig. 4 NANO CLAY MODIFIED BITUMEN MOULDS

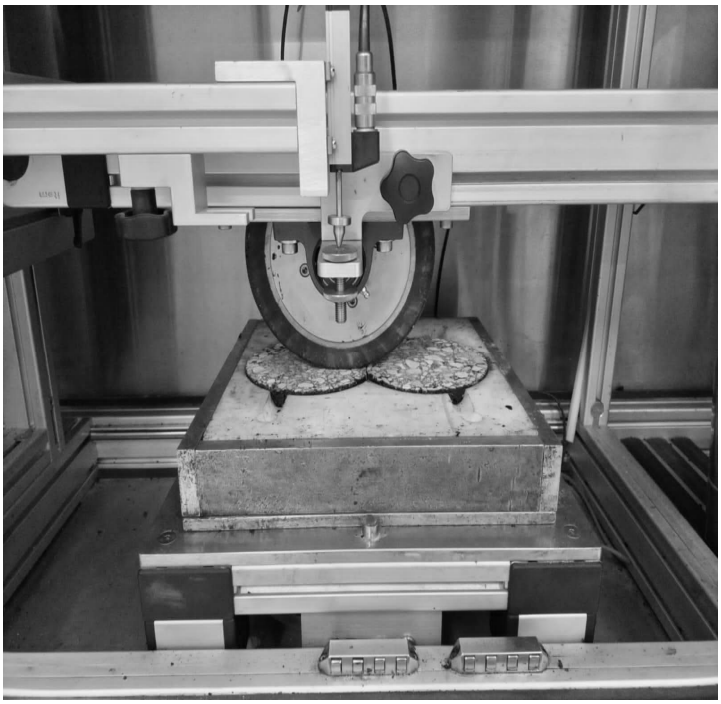

Fig. 5 HAMBURG WHEEL TRACKER TEST

In order to compare results of the modified asphalt with that of virgin asphalt, two moulds from virgin asphalt cement NRL 60/70 grade bitumen and NRL 80/100 were prepared. These were compacted using Superpave gyratory Compactor and then subjected to Wheel Tracker Test.

Fig. 6 MOULDS AFTER HWTT

VI. RESULTS AND DISCUSSION

A. Impact on Viscosity

Table 2 shows the viscosity of modified asphalt binder as a function of Nano clay percentage. It can be observed that the viscosity of the specimens is increased as the Nano clay content is increased from 0 to 4.5%. Increasing trend is observed for all binders ranging from 3% to 4.5%.

TABLE 2
% NANO CLAY AND VISCOSITY (NRL 60/70)

Nano Clay %	Average Viscosity (cP)
0%	342.2
3%	392.8
3.5%	419.1
4%	454.6
4.5%	494.9
5%	487.4

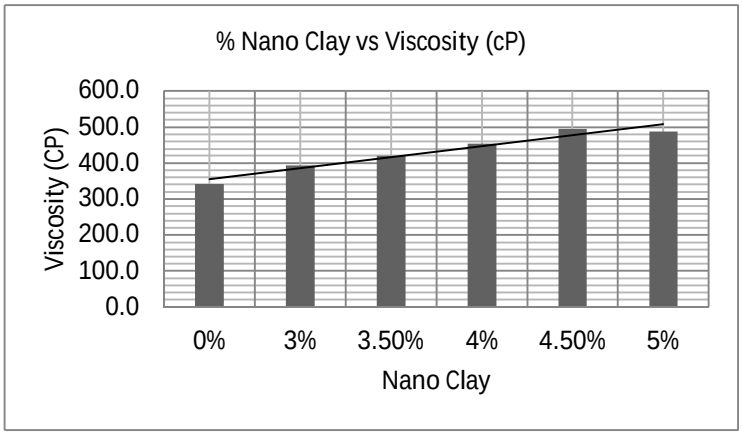

Fig. 7 % NANO CLAY VS VISCOSITY (NRL 60/70)

TABLE 3
% NANO CLAY AND VISCOSITY (NRL 80/100)

Nano Clay %	Average Viscosity (cP)
0%	346.0
3%	398.5
3.5%	418.4
4%	436.5
4.5%	465.5
5%	455.9

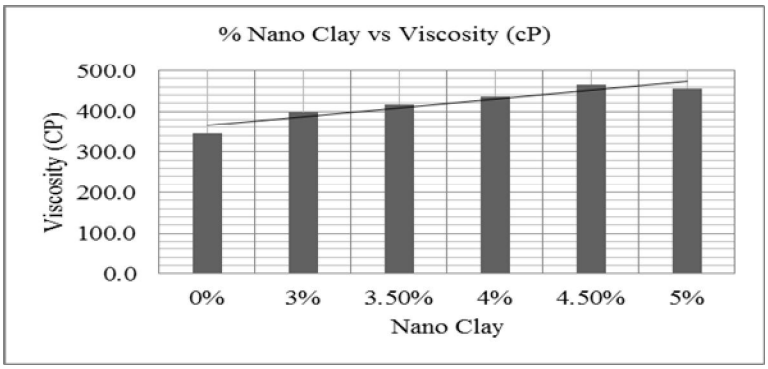

Fig. 8 % NANO CLAY VS VISCOSITY (NRL 80/100)

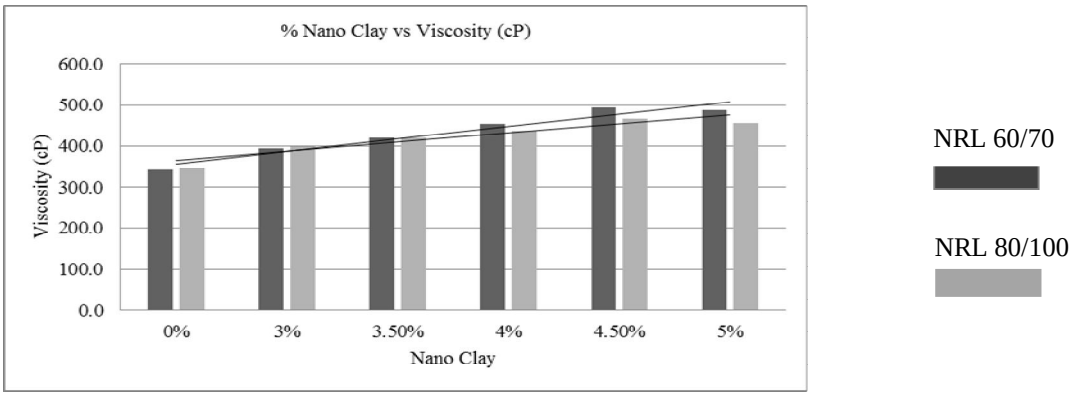

Fig. 9 COMPARISON OF MODIFIED NRL 60/70 AND NRL 80/100 Asphalt Cement

B. Rut Performance

After conducting tests on modified asphalt and virgin asphalt and comparing its results it can be observed that with the incorporation of Nano clay content, rut resistance increases and overall rutting in the modified asphalt decreases.

TABLE 4
% NANO CLAY AND RUT DEPTH (NRL 60/70)

Nano Clay %	Rut Depth (mm)
0%	2.6
3%	1.9
3.5%	1.5
4%	1.2
4.5%	0.8
5%	0.9

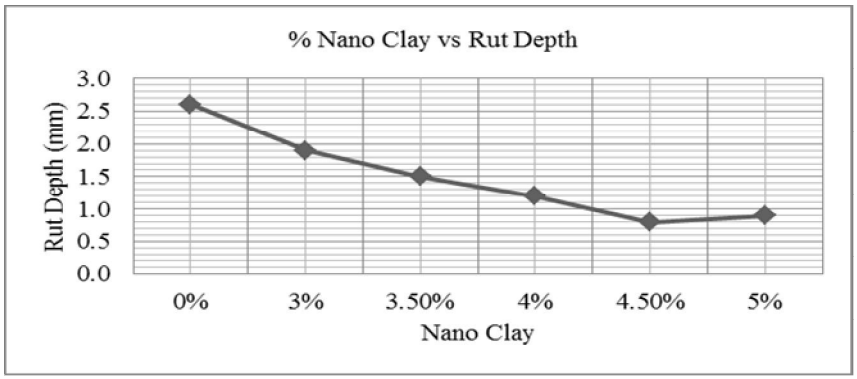

Fig. 10 % NANO CLAY VS RUT DEPTH (NRL 60/70)

TABLE 5
% NANO CLAY VS RUT DEPTH (NRL 80/100)

Nano Clay %	Rut Depth (mm)
0%	3.4
3%	2.5
3.5%	2.2
4%	1.6
4.5%	1.1
5%	1.3

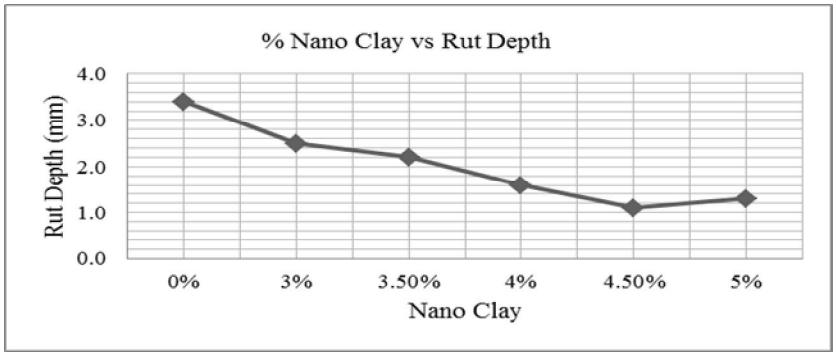

Fig. 11 % NANO CLAY VS RUT DEPTH (NRL 80/100)

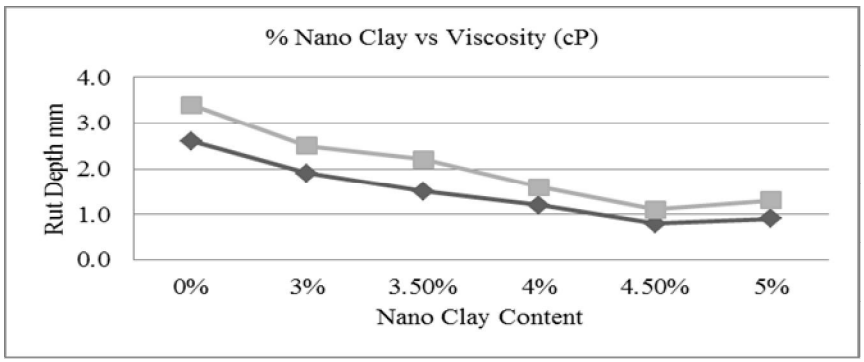

Fig. 12 Comparison of Modified NRL 60/70 And NRL 80/100 BITUMEN

VII. CONCLUSIONS AND RECOMMENDATIONS

In this study rotational viscometer was used to evaluate the flow characteristics such as absolute viscosity and Hamburg wheel tracker is used to evaluate rut performance of Nano clay modified asphalt cement.

After comparing results of modified asphalt with virgin asphalt cement, the following conclusions were carried out:

1) Viscosity of the binder is increased with the incorporation of Nano clay content. Increasing trend is observed for all binders ranging from 3% to 4.5%. The use of Nano Clay particles improved the viscosity value when compared with the original asphalt. Modified asphalt cement showed more viscosity gain at 4.5% while show a slight decreasing shift in viscosity at 5%.

2) With the addition of Nano Clay content, rut resistance increases and overall rutting in the modified asphalt decreases. The Hamburg wheel tracker test showed that, the modified samples are less prone to rutting than virgin samples. However, the modified asphalt with 4.5% Nano clay incorporation showed comparatively better resistance. This indicates that resistance of the modified asphalt to rutting was found to be a function of the quantity of the Nano clay incorporated into the virgin asphalt cement.

3) The best Nano clay content belongs to 4.5NC; by addition of Nano clay content up to 4.5% to specimens NRL 60/70 and NRL 80/100, viscosity is increased by 44.6% and 34.53% respectively. Similarly by addition of Nano clay content up to 4.5% to specimen NRL 60/70 and NRL 80/100, rutting is decreased by 69.23% and 67.64% respectively.

VIII. ACKNOWLEDGMENT

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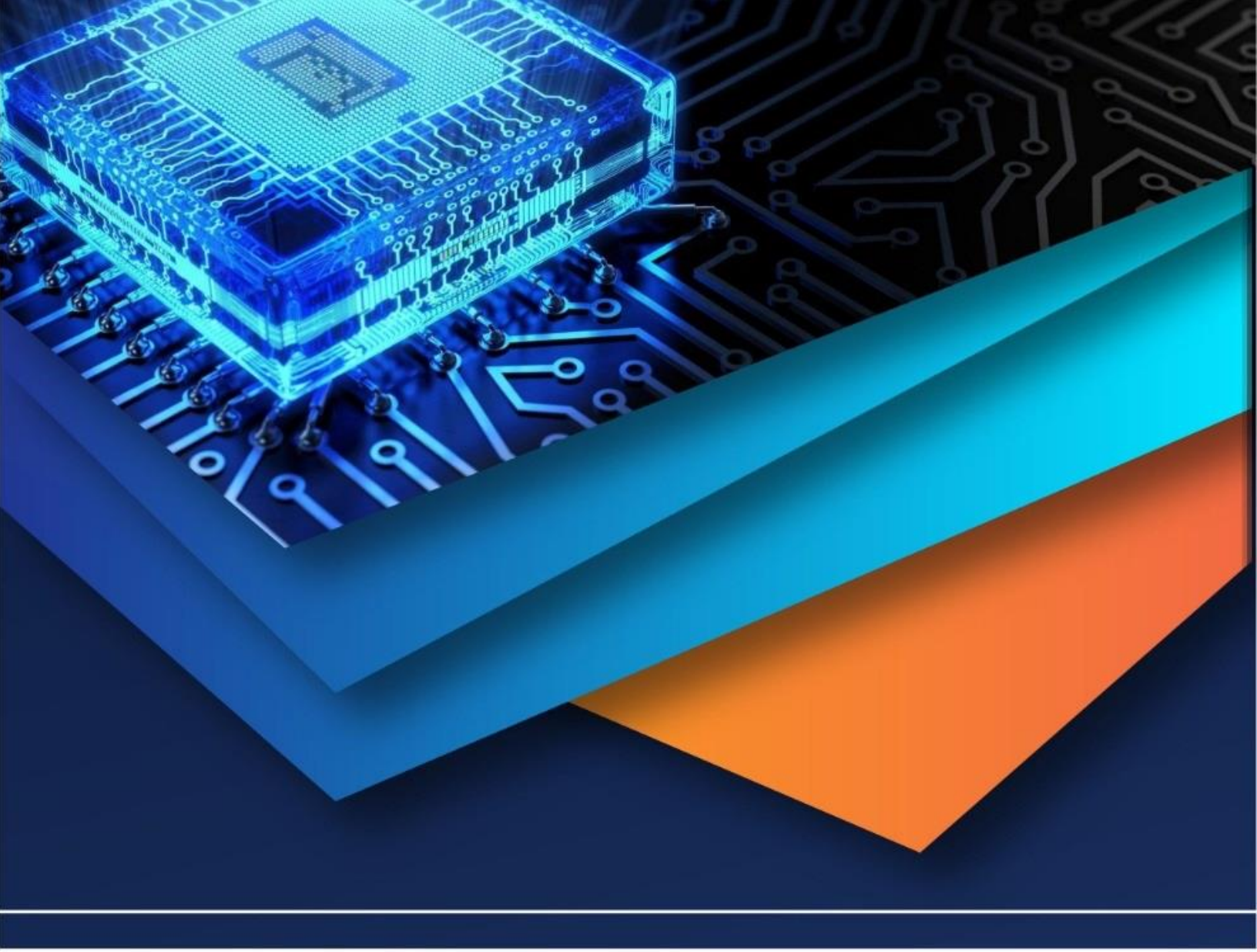

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