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Study with Cement Replacement by Marble Dust in Concrete for Rigid Pavement

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Abstract: ***The use of waste marble powder (dust) was suggested in partial replacement of cement, to produce concrete Mix. Tests were conducted on concrete mix for various times to find out their workability, compressive strength, and flexural strength. Partial replacement of cement by fluctuating percentage of marble powder reveals that increased waste marble powder ratio consequence in increased workability and compressive strengths of the concrete at respectively curing age. The marble dust from marble processing is a waste which can be utilized for concrete pavement. The use of this waste was proposed in numerous percentages as an addition to and as a substitute of cement, to produce concrete mixtures. The study's hewed that marble wastes, which are within the dust form, could be used as cementitious material in concrete mixtures where they are available, and the cost of construction is lower than ordinary concrete materials. The concrete is prepared containing 0, 5, 10, 15 and 20% waste of marble dust with cement compared to the entire quantity of normal concrete. The prepared mixtures were then investigated in conditions of their properties both in fresh and in hardened state. Tests were conducted at different times to look out compressive strength with partial replacement of marble dust in cement concrete determined for 7, 14 and 28 days. The water content used in all mixes is 0.45. The proportion conventional concrete of cement: sand: coarse aggregates are 1:1.69: 2.64.***
Keywords: Cement, Concrete, Workability, Compressive strength, Flexural strength

I. INTRODUCTION

Marble is a rock resulting from the transformation of a pure limestone. Marble dust is an industrial by-product attained during sawing, shaping, and polishing of marble. The result is that the mass of marble waste 20% of entire marble quarried as reached as extreme as masses of tons and causes a significant problem to the environment. In India, MDP is settled by sedimentation and then dumped away which ends up an environmental pollution, Moreover, to forming dust in summer and threatening both agriculture and public health. Marble dust is not only the inexpensive material but also improves the properties of the concrete so by varying marble dust contents the mechanical and physical characteristics of fresh and hardened concrete can be improved. Now-a-days the cost of cement is increasing so if we use the waste material in the production of the concrete, so we decrease the price of rigid pavement.

A. Pavement

Road can be multi-layered structural part of the road which is subjected to stresses imposed by traffic load applied, as well as to worsening from the effects of weather and the abrasive action of moving vehicle load. Pavement is the actual travel surface especially made long-lasting and functional to withstand the traffic load travelling upon it. Pavement allows friction for the vehicles thus providing comfort to the driver and transfers the traffic load from the upper surface to the natural soil. A satisfactory pavement design is one that can withstand these effects for a required period. A pavement consists of a multi-layer system, which is formed of several layers of compacted unbound aggregates or bound materials.

B. Types of Pavement

Road pavement is generally divided into two categories, namely:

1) Rigid pavement
2) Flexible pavement

The road pavement which possess sufficient flexural strength to transmit the wheel load stresses to a wider area below and provide great resistance to deformation under the wheel loads are identified as rigid pavements. Features of rigid pavement are associated with rigidity or flexural strength or slab action so load is distributed over a wide area of sub-grade soil. The rigid pavements are normally made of Portland cement concrete and therefore called cement concrete (CC) pavements. Plain cement concrete pavement slabs manufactured from specified strength characteristics are laid, with or without steel reinforcement at the joints.

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Since there is only one layer of material between the concrete and sub-grade, this layer can be called as base or sub-base course. In rigid pavement the stresses are not transferred from particles to particles to the lower layers as within the case of flexible pavement layers. The rigid pavement has capable of transmitting the wheel load stresses through a way wider area below the pavement slab. The rigid pavement does not get deformed to form of the supporting layer below, because the pavement slab can bridge the gap or slight differences of the surface of the supporting layer below.

The main difference in the structural behaviour of rigid pavement is compared to the flexible pavement is that the critical condition of stresses in the rigid pavement is the maximum flexural stress occurring at certain critical locations of the CC slab due to combined action of wheel load and the temperature changes.

Flexural stresses are developed at different locations of the CC pavement slab reckoning on the relative location of the wheel load with respect to its position on the CC slab and the also the effect of temperature changes at the situation at the purpose of your time of the day and night. Rigid lasts much, much longer (30+years) compared to flexible pavement (5-10 years). Generally, a well designed and constructed pavement does not require major maintenance work except maintenance o of drainage and joints in cement concrete.

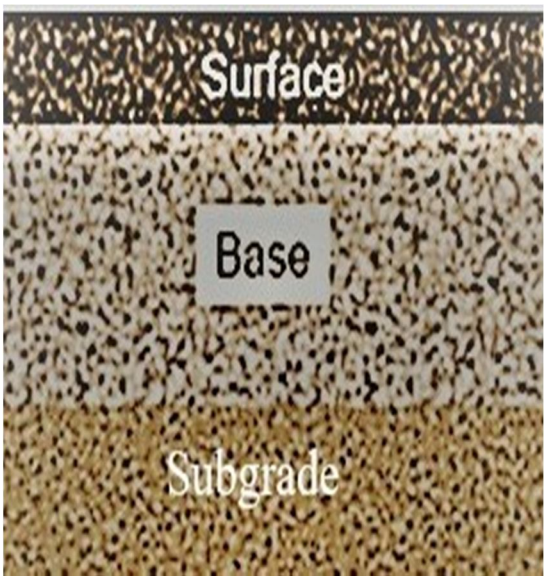

Fig. 1 Rigid pavement

II. LITERARTURE REVIEW

A. Valeria, et al., (2005) [1] determined the characterization of marble powder for its use in mortar and concrete. From the physical and chemical point of view they have categorized the marble powder using it in mortar and concrete production. A powder obtained as a by-product of marble sawing and shaping was characterized from a chemical and physical point of view to use it as a mineral addition for mortars and concretes, especially for self-compressing concrete. This marble powder showed an extremely high Blaine fineness value of about 1500 m^2/kg, with 90 % of particles finer than 50 micron and 50 % under 7 micron. In terms of mechanical performance, 10 % substitution of sand by the marble powder in the presence of a super plasticizing admixture provided maximum compressive strength at the same workability level, similar to that of the reference mixture after 28 days of curing. Moreover, an even more positive effect of marble powder is evident at early days, due to its filler ability. Results obtained show that 10% substitution of sand by the marble powder provided maximum compressive strength at about the same workability.

B. Hanifi Binici (2007) [2] found that marble dust powder has higher compressive strength than corresponding limestone dust concrete having equal w/c and mix amount. Seven control mixtures were produced in three series with control mixes having 400kg cement content. These control mixes were modified to 5, 10, 15% and Lime dust in place of fine sand aggregates. The compressive strength of concrete was measured for 7, 28, 90, 360 days and sodium sulphate resistance were for 12 months. Result indicates that MD and LD fine aggregate concrete has good workability and abrasion resistance is comparable to that of normal concrete. It also indicates that increase dust content increase in the sodium sulphate resistance of the concrete.

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C. Ilker Bekir Topcu et al. (2008) [3] studied the effect of waste marble dust content as filler on properties of self-compacting concrete. Day by day, the amount of the marble dust (MD) as a waste material is significantly of increasing in Turkey. Therefore, the utilization of the waste MD in self-compacting concrete (SCC), as filler material, is the main objective of this study. Besides, the MD is used directly without attempting any additional process. Thus, this would be another advantage for this objective. For this purpose, MD has replaced binder of SCC at certain contents of 0, 50, 100, 150, 200, 250 and 300 kg/m^3. After then, slump-flow test, L-box test and V-funnel test are conducted on fresh concrete. Furthermore, compressive strength, flexural strength, ultrasonic velocity, porosity and compactness are determined at the end of 28 days for the hardened concrete specimens

D. Huseyin Yilmaz Aruntas, et al., (2010) [4] studied the Utilization of waste marble dust as an additive in cement production. In this experimental study, the usability of waste marble dust (WMD) as an additive material in blended cement has been investigated. For this purpose, waste marble dust added cements (WMDCs) have been obtained by inter grinding WMD with Portland cement clinker at different blend ratios: 2.5 %, 5.0 %, 7.5 % and 10% by weight. 40× 40× 160 mm mortar prisms has been produced with the obtained cements. Strength tests have been carried out on mortar specimen at 7, 28, and 90 days.

E. Baboo Rai , et al., (2011) [5] have done their research on Influence of Marble dust powder/granules in Concrete mix. Partial replacement of cement and usual fine aggregates by varying percentage of marble powder reveals that increased waste marble powder result in increased workability and compressive strengths of the mortar and concrete.

F. N. Gurumoorthy, (2011) [6] investigated the performance of concrete contained marble dust as cement replacement, mix was prepared with cement and sand blended with marble dust with replacement from 10%, 20%,25% and 30%. The investigation indicates that replacement of cement by MD at different ratio in concrete production, consequences higher compressive strength, split tensile strength and flexural strength as of concrete samples without marble dust.

G. Vaidevi C., et al., (2013) [7] found that the use of this waste was proposed in different percentages both as an addition to and instead of cement, to produce concrete mixtures. The study showed the cost of these cementitious material decreases cost of construction when replaced by different percentages of MD. Compressive test and tensile tests were conducted. 10% replacement gives the best result and for every 10 bags of cement, the addition of 10% of marble dust saves 1bag of cement and 1 bag of cost.

H. Noha M. Soliman, et al., (2013) [8] investigated that workability increased by using small amount of marbles powder ratio as a replacement of cement and leads to increase the compaction and strength of concrete. The increasing of marble powder ratio as a replacement of cement over the optimum dosage to the segregation of aggregates and bleeding of cement and aggregates lead to decrease the resistance of concrete. Increasing compressive strength by about (25% and 8%) for the marble powder replacement ratio (5% and 7.5 %) compared to the control mix.

I. Vakkar, Er. Neeraj Kumar, et al., (2019) [9] had done their research on partial replacement of pulverised plastic as fine aggregate in rigid pavement. The Indian concrete industry is today consuming millions of tonnes of concrete every year and it is expected to increase further in upcoming years. All the materials required to produce such huge quantities of concrete come from the earth's crust, thus The plastic is one of the recent engineering materials which have appeared in the market all over the world.. Plastics were used in bath and sink units, corrugated and plain sheets, floor tiles, joint less flooring, paints and varnishes and wall tiles. There has been a steep rise in the production of plastics in last 30 to 40 years. Major part of total waste is plastic products, which deserves special attention on account of non- biodegradable property which is creating a lot of problems in the environment. There is however now increase in awareness regarding the utilization of plastic as a useful building material in our country.

III. MATERIALS AND METHODOLOGY

The materials used in this study for making concrete mixture are cement, fine aggregate, coarse aggregate, marble dust and water as under:

A. Cement

In general, it can be defined as material which possesses particularly good adhesive and cohesive properties which makes it possible to bond with other material to form a compact mass.

Table 1 Properties of cement 43 grade

Characteristics	Values Obtained
Specific Gravity	3.13
Standard Consistency	29%

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B. Aggregate

Aggregate is broad category of basic material used in construction, sand, gravel, crushed stone, dust, broken bricks etc.

1) Fine Aggregates: Fine aggregates are those which can pass through 4.75mm IS-sieve, the residue of the sieve is not considered.

Table 2 Sieve analysis of fine aggregates

S. No.	IS-Sieve (mm)	Wt. Retained (gm)	%age Retained	%age passing	Cumulative % Retained
1	4.75	8	0.8	99.2	0.8
2	2.36	45	4.5	94.7	5.3
3	1.18	159	15.9	78.8	21.2
4	600 µ	288	28.80	50	50
5	300 µ	364	36.4	13.6	86.4
6	150 µ	116	11.6	2	98
7	Pan	20	2	SUM	261.7

Fineness Modulus = 2.61

2) Coarse Aggregates: The aggregates which are retained over IS sieve 4.75mm are termed as coarse aggregate. The coarse aggregate may be crushed gravels or stone obtained by crushing of gravel or hard stone.

Table 3 Properties of coarse aggregates

Characteristics	Value	
Colour	Grey	
Shape	Angular	
Maximum size	20mm	10mm
Specific Gravity	2.61	2.70
Water Absorption	0.4%	0.5%

Table 4 Sieve analysis of coarse aggregate (10mm)

S. No.	IS-Sieve (mm)	Wt. Retained (gm)	%age Retained	%age Passing	Cumulative % Retained
1	20	449	22.45	77.55	22.45
2	10	415	20.75	56.80	43.2
3	4.75	1055	52.75	4.05	95.95
4	2.36	81	4.05	0	100
5	1.18	0	0	0	100
6	600	0	0	0	100
7	300	0	0	0	100
8	150	0	0	0	100
9	Pan	0	0		
Total		2000		SUM	661.15
Fineness Modulus (FM)= 6.61					

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C. Marble Dust

Marble dust is a semi liquid substance consisting of particles originating from the sawing and the polishing processes and water used to cool and lubricate the sawing and polishing machines.

Table 5 Physical properties of marble dust

Properties	Mass percentage
Surface area	11.4×10^{3}
Bulk density	986(kg/m^{3})
Specific gravity	2.5
Colour	Light grey

D. Water

Water is very important ingredient of concrete. Water used for concreting should be free from organic and inorganic matters. Potable water should be used for concreting.

IV. RESULTS

Outcomes from different tests which are conducted on fresh and hard concrete are described below:

A. Fresh concrete

The concrete slump test is an empirical test that measures the workability of fresh concrete. More specifically, it measures the consistency of the concrete in that specific batch. Test performed to check the consistency of freshly concrete are as under:

1) *Slump value:* Slump values of a concrete sample have been tested for a different sample of mix with different percentages of marble powder as replacement of cement. The following table-4.1 shows the slump values for M30 grade of concrete for various percentage of waste marble powder and represented in graph.

Table 6 Slump value with different %age of marble dust

Sample	Slump value (mm)
Conventional concrete	80
Concrete with 5% marble powder	90
Concrete with 10% marble powder	110
Concrete with 15% marble powder	115
Concrete with 20% marble powder	125

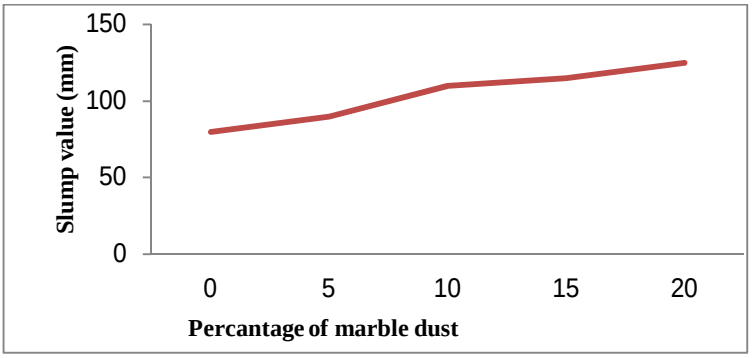

Fig. 2 Slump value with different %age of marble dust

The height difference between the height of subsidence concrete and mould cone in mm is ‘slump value of concrete.

Fig. 2 Slump value with different %age of marble dust directly proportional to %age of marble dust. Graph shows it has more workability. As amount of marble dust increased more water required to mix.

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B. Hard Concrete

Concrete strength can be defined in three different ways: compressive, flexural, tensile strength. Strength of concrete depends upon the number of materials and quantity and quality of materials. Also, manner of mixing, moulding and curing.7 days, 14 days, 28 days when strength test of concrete considered.

1) *Compressive Strength:* This test consists of determining compression strength of 7, 14 and 28 days. Compression strength of cement is the property which decides the qualities of concrete strength. The compressive strength of concrete primary property that is carefully studied in almost all research works. Nine specimens for each mix were tested and the corresponding values were observed and average values were taken for discussion.

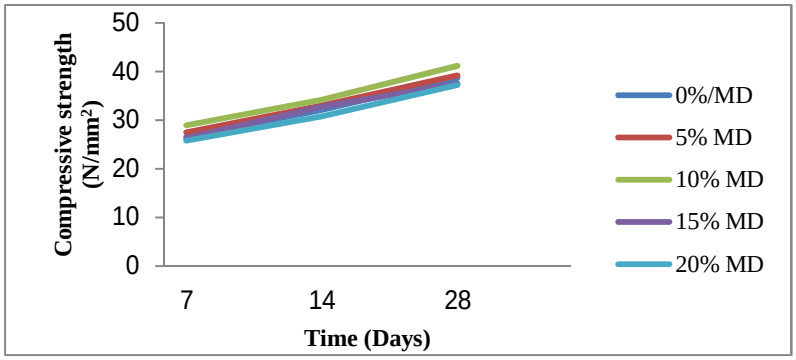

Fig. 3 Compressive strength on concrete with different %age of marble dust

From the Fig. 3 which shows the effect of replacement of cement with MD, it was observed that the compressive strength of concrete increased as the percentage replacement level of MD was increased by 5% to 10% for all ages. However, at the later curing ages of 7, 14 and 28 days, the compressive strength increased up to 10% replacement and then subsequently decreased. It also show the variation in compressive strength of concrete mixes cast using marble dust in varying proportions, as replacement of cement It can be observed form the above mentioned table and figures that by keeping a varying percentage of marble dust, there was slight increase which was observed at 10% but subsequently at higher levels of 15% and 20% the strength decreased. The highest early age strength, 7 days, could be achieved by using only 10% marble dust as cement replacement.

2) *Flexural Strength:* The deflection and cracking behaviour of concrete structure to a large extent depends upon the flexural tensile strength of concrete. The flexural strength of concrete has a direct relation with the thickness of the slab its evaluation becomes the most important component of pavement design. Flexural strength of concrete with different ratio of marble dust.

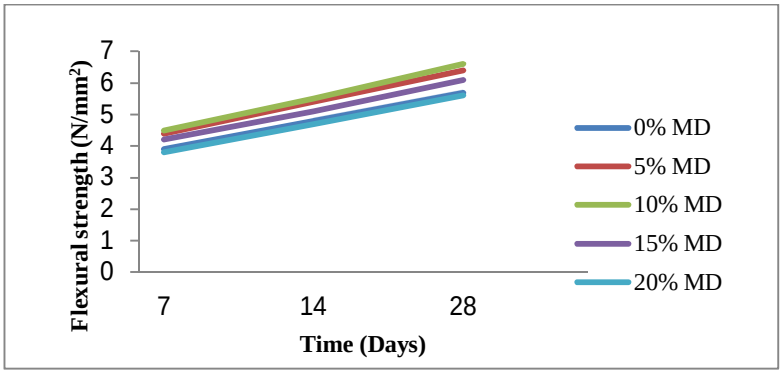

Fig. 4 Flexural strength on concrete with different %age of MD

From the fig. 4 show the effect of replacement of cement with marble dust on the flexural strength behaviour of concrete and depicts variation in flexural strength according to different curing ages. However, at the curing age of 28 days, the flexural strength increased up to 10% replacement and then subsequently decreased. However, the flexural strength was higher for all levels at 28 days, as compared to both the control mix as well as mixes containing only marble dust.

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It can be observed form the above-mentioned table and figures that by keeping a fixed percentage of marble dust in the mix, there was a slight increase which was observed at 10% at 7 days, but subsequently at levels of 15% and 20% the strength decreased. These observations indicate that the optimum replacement level of cement with the marble dust used in 10%. The highest early age flexural strength, 7 days, could be achieved by using only 10% marble dust as cement replacement. The highest strength in flexure at 28 days could be achieved 10% marble dust.

V. CONCLUSION

With the concern tests done on partial replacement of cement by marble dust sample the following outcomes are found:

A. As per chart shown in fig. 2 it is clear that slump value is directly proportional to increasing percentage sample of replaced concrete.
B. Compressive strength test and flexural strength test shown the same effect on replacement i.e. the value is increases as increase in %age of marble dust upto 10% and of the increase in %age of marble dust graph shows the decreases in strength. So, optimum %age for replacement is 10%.
C. Compressive strength of sample increased upto 10% replacement i.e. 8.64% for 7 days, 6.5% for 14 days and 6.47% for 28 days and decreased as increases in %age after 10% i.e. 10.76% for 7days, 9.94% for 14 days and 9.48% for 28 days.
D. Flexural strength of sample increased upto 10% replacement i.e. 15.38% for 7days, 14.58% for 14 days and 15.78% for 28 days. And decreased as increase in %age after 10% i.e. 15.6% for 7 days, 14.55% for 14 days and 15.15% for 28 days.
E. If percentage of marble dust used more than 10% in concrete than modified concrete will neither feasible nor economical.

VI. FUTURE SCOPE

This project was mainly focused on the partial replacement of cement with marble dust at different percentage in concrete. Scopes of future work are as under:

A. Marble dust concrete with plasticizer for higher grade of concrete.
B. Study of Marble dust concrete varying water cement ratio.
C. Use another relevant type of waste as replacement material.

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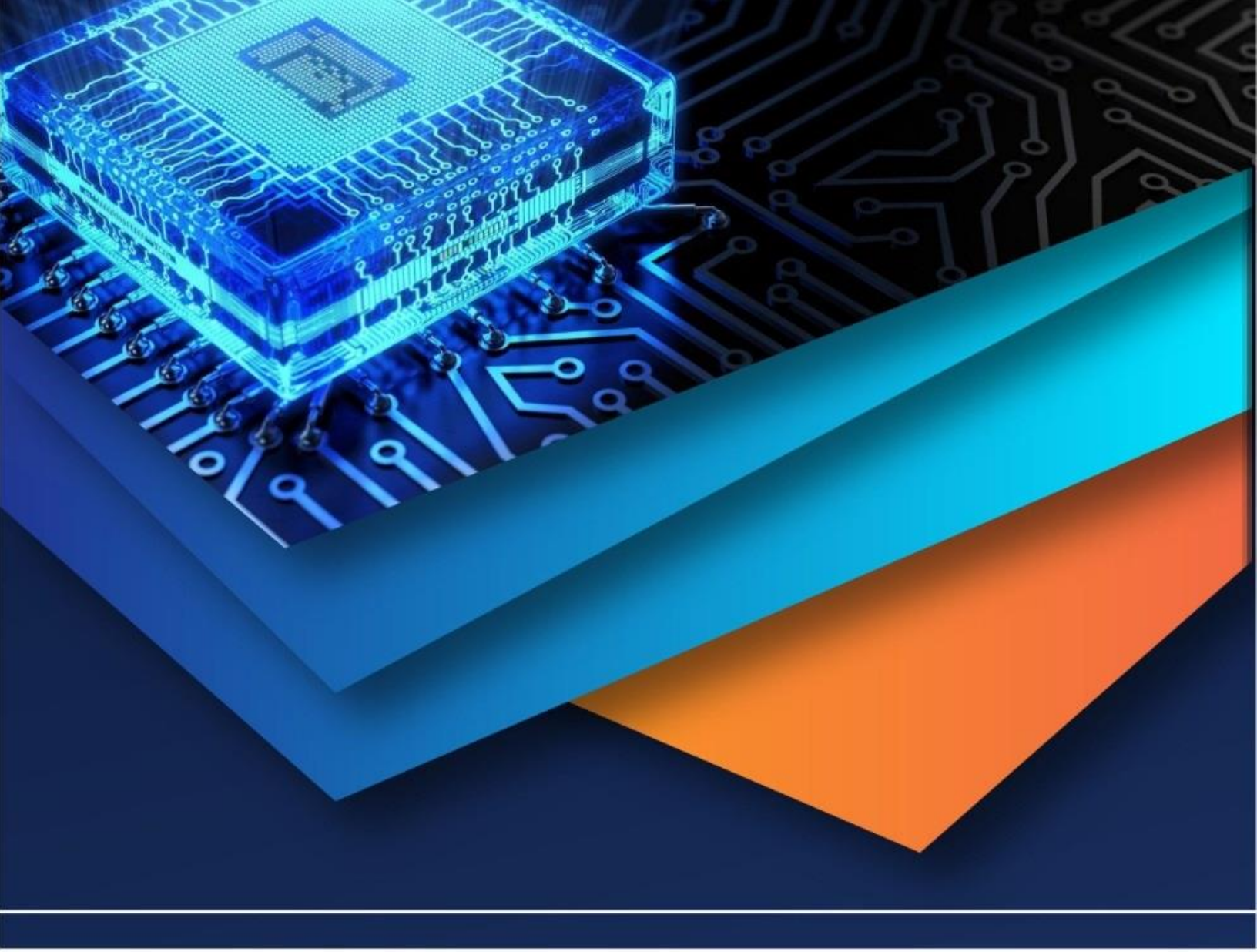

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