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Mechanical Performance of Lean Mortar by Using Waste Glass Powder as a Replacement of Cement

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Abstract: In present life, glass is used in construction, soft-drink bottles, medicinal bottles, automobiles, mirrors, windscreen, doors, windows, decorative items, tube lights, bulbs and other electronic gadgets etc. Glass has limited life period, so after completion of its utility period it is either stock piled or sent to landfills without being recycled. The aim of this work was to use the waste glass powder (WGP) as a partial replacement of cement for making mortar and compare its performance with normal cement mortar mix of ratio 1:3. In this research various types of waste coloured glasses and cleared glasses were used for making glass powder. Glass powder was obtained from grinding of waste glass. The main goal of this study is to demonstrate the possibility of using waste glass powder (WGP) as a partial replacement of cement which is used in mortar

In this research work cement mortar cubes were used to understand the influence of the waste glass powder (WGP) on the compressive strength. A series of tests were conducted to study the effect of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% replacement of cement by waste glass powder (WGP) on compressive strength test at 7 days and 28 days. Several test such as Consistency test, Initial and Final setting time, and soundness value of cement paste were also determined. And also the particle size effect was evaluated by using glass powder of size 75µm-90µm and glass powder of size less than 75µm. A total of 17 trial mixes were prepared for both sizes of glass powder.

Test results indicated significant increment in the strength of mortar with addition of waste glass powder (WGP) up to 30 % replacement of cement. However after further increasing the percentage of waste glass powder, a drop in strength of mortar was noted. The present study shows that waste glass powder (WGP), if particle size is less than 75µm shows the higher compressive strength compare to normal mix.

Keywords: Waste Glass Powder (WGP), Cement Mortar, Compressive Strength, Soundness test, Waste Utilization

I. INTRODUCTION

Glass waste is the major issues of environmental problem. Every year the amount of glass wastes generated by glass recycling and manufacturing is very high while the recycling efficiency of waste glass wastes is very low. According to “Indian Institute of packaging” in India 5 million metric tons of glass waste generated per year. The amount of waste glass not recycled are dumped or discarded and has many negative impacts on the human health, society and environment. Some countries currently use glass as a fine aggregate in Portland cement concrete as construction material. In day-to-day life, glass is used in construction, soft drink bottles, medicinal bottles, vehicles, mirrors, windscreens, doors, windows, decorative items, tube lights, bulbs, and other electronics items. Glass has a limited life span, so after completion of its utility period, it is either stock piled or sent (non-recycled) to landfills. Non-degradable waste has been a major issue in the 21st century. The disposal of waste glass in landfills is not an environmentally friendly solution because glass is non-biodegradable waste. Hence, the waste glass increases with the usage of glass has increased considerably, then the increase waste disposal. But, the glass waste is non-biodegradable that affects the surrounding environment. As a construction material waste glasses and waste glass powder has been used to decrease the environmental problems. The fine waste glass aggregates and coarse waste glass aggregates could cause the alkali-silica reaction (ASR) in concrete, but the waste glass powder could decrease the tendency ASR. Therefore, the waste glass powder is used as a replacement of supplementary cementitious construction materials.

II. LITERATURE REVIEW

Džigita Nagrockienė, et al (2021) have studies Every year, millions of tons of waste glass are generated all over the world and disposed in landfills. Utilization of this waste by substituting a certain share of cement in cement mortars can contribute to the reduction of environmental pollution in two aspects: the utilization of waste and the reduction of the cement content in cement-based mortars. The cement industry is responsible for approximately 6% of global CO2 emissions. Seven different mortar mixes, containing between 0% and 30% of waste glass powder added by weight of cement, were analyzed. The following physical and mechanical properties of the mortar mixes were measured: compressive strength, flexural strength, and density.

The test results revealed that waste glass powder can be used in small amounts in cement-based mortars to reduce the amount of cement and to utilize waste glass. A higher performance, modified cement-based mortar can be produced for civil engineering applications by replacing 5% with waste glass powder. The linear regression equations obtained illustrate the relationships between the density and compressive strength, and between density and flexural strength at 28 days.

Houssam Eddinne, et al (2021) have studies Every year, millions of tonnes of glass waste pose terrible problems related to the environmental condition all over the world. The glass is mainly composed of silica. Its use in concrete could be a beneficial solution for the environment and also economic problems. In this mini review, the different possibilities of the valorization of glass waste by substitution of aggregates and cement in concrete have been explored. Its effects on the physicochemical and mechanical characteristics were examined in the main research in this direction. The use of waste glass in concrete can offer an improvement in concrete performance and an asset for participation in sustainable development by reducing this waste.

Abhay Singh, et al (2019) have studies use the waste glass powder as a partial replacement of cement for making mortar and compare its performance with normal cement mortar mix of ratio 1:3. In this research various types of waste colored glasses and cleared glasses were used for making glass powder. Glass powder was obtained from grinding of waste glass. This research deals with the study on the utilization of waste glass powder as a partial replacement of cement which is used in mortar. In this research cement mortar cubes were used to understand the influence of the waste glass powder on the compressive strength. A series of tests were conducted to study the effect of 5%, to 40% replacement of cement by waste glass powder on compressive strength test at 7 days and 28 days.

Jitendra B. Jangid et al (2015) studied on the use of waste glass powder as the partial replacement of cement in concrete production. In this study waste glass powder replaced at varying percentage and tested for its Workability, Split Tensile Strength, Alkalinity test, Compressive Strength, Density Measurement, Volume of permeability test, Water Absorption test, Ultrasonic Pulse Velocity test for the age of 7, 28 days and it was compared with those of normal concrete. The overall test result shows that waste glass powder could be utilized in concrete as a substitute of cement by replacement. By the test results of this study 20% replacement of glass powder gives higher strength.

Sachin V. Bhosale, et al (2014) have studied the green concrete by utilization of waste glass powder & industrial waste sand for construction industry. In this research paper five design mixes were used at 7days, 28 days, 54 days and 90 days strength comparison with and without curing compound. This research shows that the utilization of Industrial Waste Sand (IWS) in large volumes. The waste glass powder grinded below 13 µm shows the same pozolanic action. 13 µm size is very small it act as the infill for the fine aggregate and increases the density along with the C-H-S gel formation which gives the strength to the structure in long run. 20 % replacement Glass powder gives high early days compressive strength.

III.MATERIAL AND METHODOLOGY

A. Cement

Ordinary Portland cement is the most widely used in the construction cements. Cement is a greenish-grey powder which is obtained from finely grinding the clinker made by strongly heating a blend of argillaceous and calcareous minerals. The main raw material in cement blend is high-calcium limestone, known as cement rock, and shale or clay. The main constituent of ordinary portland cement are lime, silica, alumina, Calcium sulphate, iron oxide, magnesia, sulphur and alkalies etc. Lime is the chief ingredient of ordinary portland cement and its proportion is properly regulated. In ordinary portland cement silica increases the strength of the cement. By the use of alumina cement set quickly. In ordinary portland cement gypsum helps to retard the setting action of cement or gypsum increases the initial setting time of the cement. In ordinary portland cement iron oxide gives the colour to the cement. In ordinary portland cement magnesia impart the strength and sulphur impart the soundness of cement. In ordinary portland cement excess of alkalies make cement efflorescent. In this study OPC 43 grade cement brand name “Ultra cement” was used.

B. Fine Aggregate

Fine Aggregate is a naturally occurring granular material. Sand is composed of finely divided rock and mineral particles. The main ingredient of sand is, in non-tropical coastal settings and inland continental settings, is silica ($SiO2$), usually it is in the form of quartz. It is the most common mineral resistant to weathering. It is used as fine aggregate in concrete and mortar.

Sand is a collection of grains of mineral matter derived from the disintegration of rocks. Sand is specify from gravel only by the size of the particles or grains, but is differ from clays which contain organic materials. Sands that have been and separated from the organic material by winds or by the action of currents of water across arid lands are generally quite uniform in size of grains. Commonly commercial sand is obtained from sand dunes formed by the action of winds and from riverbeds.

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C. Waste Glass Powder (WGP)

The waste glass powder used in this research project originates from grinding of waste window glass particles. These waste glass particles are collected from local market. Two different forms of glass are used, particle size less than 75µ and between 75µ to 90µ. To remove the organic residue glass particles were washed with water.

Glass is a transparent material and it is produced by melting a blend of materials such as silica, CaCO3, and soda ash at high temperature followed by cooling during which solidification occurs without crystallization. By manufactured products such as sheet glass, bottles, glassware, and vacuum tubing glass is widely used in our lives. The quantity of waste glass is increased over the recent years due to an ever-growing use of glass products like bottles and sheet glass etc. Mainly glass waste had been dumped into landfill sites. Glasses are not biodegradable so that land filling of waste glasses is undesirable because, which makes them less environment friendly. So we use the waste glass in concrete to become the construction economical as well aseco-friendly.

(a) Particle size 75µ-90µ (b) Particle size <75µ

Fig. 3.3: Waste Glass Powder of Different Grain Size

1) Physical Properties of Glass

Table 3.3.1: Physical Properties of Glass

S. No.	Characteristic	Value
1	Density	2500 kg/m^3
2	Modulus of elasticity E (Young's modulus)	73 X 10^3 N/mm^2
3	Poisson's ratio m	0.22
4	Compression resistance	800 - 1000 MPa
5	Bending strength	45 MPa
6	Refractive index n_d (l = 587.6 nm)	1.514
7	Hardness	470 HK
8	Strain Point	511°C
9	Anneal Point	545°C
10	Soften Point	724°C
11	Thermal conductivity	0.8W/mK
12	Thermal expansion	9.10-6 K-1

D. Methodology

A nominal mix of mortar of proportion 1:3 was adopted for the present study. The first mix MC (control mix) is having only cement as binder. The MCG series had glass powder as replacement of cement. The compressive strength test were conducted to monitor the strength development of mortar containing 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% & 40% of glass powder as cement replacement. The particle size effect of glass powder studied by using glass powder of size between (75-90) μ and less than 75 μ. Normal consistency test is conducted to study the normal consistency of cement.

- Compressive strength tests of mortar were conducted in two series.
- In first Series glass powder of size between 75 μ to 90 μ were used as partial replacement of cement.
- In second series glass powder of size less than 75 μ were used as partial replacement of cement.
- Seventeen numbers of standard cubes (70.6 X 70.6 X 70.6 mm) were cast to measure the compressive strength after 7 days and 28days.

1) Mix Proportion for Mortar Cube(1:3)

The control mix served as the basis for comparison of the test mix in both parts of experimental program. The first part of Experimental Program the cement blends study was devoted to examining the how cement mortar properties varies when sand type grading and blend ratio were changed.The cement in the mix are blended as discussed previously. Including the control mortar mixes17 trials were tested in this study.

Table 3.5.4.2 Mix proportion for mortar cube with cement blend

Sample No.	Grain size of glass powder	Replacement of Cement by Waste Glass Powder (%)	Quantity of Cement Blend (gm.)		Quantity of Sand (gm.)		
			OPC	WGP	< 2mm & > 1mm	< 1mm & > 500μ	< 500μ & >90μ
MC	75μ - 90μ	0	200	0	200	200	200
MCG1		5	190	10	200	200	200
MCG2		10	180	20	200	200	200
MCG3		15	170	30	200	200	200
MCG4		20	160	40	200	200	200
MCG5		25	150	50	200	200	200
MCG6		30	140	60	200	200	200
MCG7		35	130	70	200	200	200
MCG8		40	120	80	200	200	200
MCG9	< 75μ	5	190	10	200	200	200
MCG10		10	180	20	200	200	200
MCG11		15	170	30	200	200	200
MCG12		20	160	40	200	200	200
MCG13		25	150	50	200	200	200
MCG14		30	140	60	200	200	200
MCG15		35	130	70	200	200	200
MCG16		40	120	80	200	200	200

IV. RESULTS AND ANALYSIS

A. *Compressive Strength*

The results of compressive strength testing of mortar cubes are presented in Table 4.1.1 and Table 4.1.2 for First series with 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% & 40% cement replacement by glass powder of grain size (75µ - 90µ) and Second series with 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% & 40% cement replacement by glass powder of grain size (<75µ) respectively. The compressive strength values reported are the average of three test cube results. Fig.4.1.1 and Fig.4.1.2 are graphical representation of strength development of mortar cubes of various mixes for the First series and second series respectively.

1) Compressive Strength of different binder mixes of OPC with WGP (of size 75µ - 90µ) after 7 days and 28days were tabulated below in Table 4.1

Table 4.1.1 7 days & 28 days Compressive Strength for Cement blend with Waste Glass Powder of size (75µ-90µ)

Sample No.	Replacement of Cement by Glass Powder (%)	Compressive strength in (N/mm^2)	
		7 days	28 days
MC	0	37	51.5
MCG1	5	35.5	52
MCG2	10	35	52.4
MCG3	15	38	55
MCG4	20	37.5	53.5
MCG5	25	36	51.5
MCG6	30	33	50
MCG7	35	32	48
MCG8	40	30	45.5

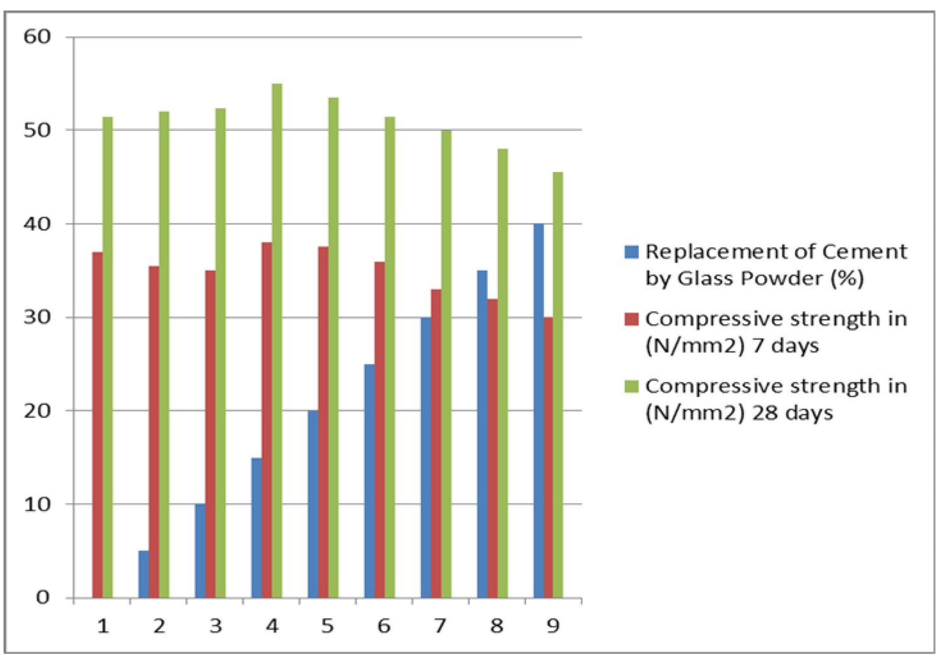

Fig 4.1.1 7 days & 28 days Compressive Strength for Cement blend with Waste Glass Powder of size (75µ-90µ)

2) Compressive Strength of different binder mixes of OPC with WGP (of size < 75µ) after 7 days and 28days were tabulated below in Table 4.1.2

Table 4.1.2 7 days & 28 days Compressive Strength for Cement blend with Waste Glass Powder of size (< 75µ)

Sample No.	Replacement of Cement by Glass Powder (%)	Compressive strength in (N/mm^2)	
		7 days	28 days
MC	0	35.5	50
MCG9	5	35	52
MCG10	10	37	54.5
MCG11	15	38	55.5
MCG12	20	36	54.5
MCG13	25	35.5	51.5
MCG14	30	33.5	50.5
MCG15	35	32.5	47
MCG16	40	31	45.5

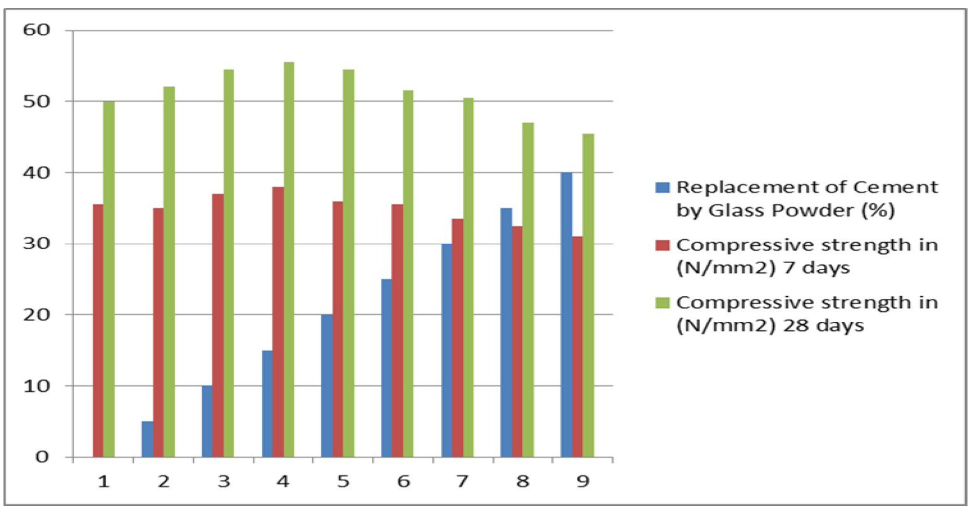

Fig 4.1.2 7 days & 28 days Compressive Strength for Cement blend with Waste Glass Powder of size (< 75µ)

From the above tables, we can conclude that early or 7 days strength and 28 days strength increases with increase in percentage of replacement by glass powder up to 30%. But 7 days and 28 days strength decreases with replacement by glass powder above 30%. 28 days strength is more in case of replacement by glass powder of size (< 75µ). The reason for gain of 28 days strength in glass powder of size (< 75µ) could be fast reaction between cement and glass particles due to fine nature. All binder mixes shows that up to 30% replacement of cement glass powder increase the compressive strength with increasing dose of glass powder. The 28 days strength increases optimal for 15% replacement of cement by glass powder of size (75µ-90µ) and increase is more in case of glass powder size (<75µ).

V. CONCLUSION

The result of the study shows that there is great potential for the utilization of waste glass powder (WGP) in mortar as replacement of cement. From the present study, it can be concluded that up to 30% of cement replacement by glass powder in mortar mix gives higher strength without any unfavorable effect.

All binder mixes shows that up to 30% replacement of cement glass powder increase the compressive strength with increasing dose of glass powder. The 28 days strength increases optimal for 15% replacement of cement by glass powder of size (75µ-90µ) and increase is more in case of glass powder size (< 75µ).

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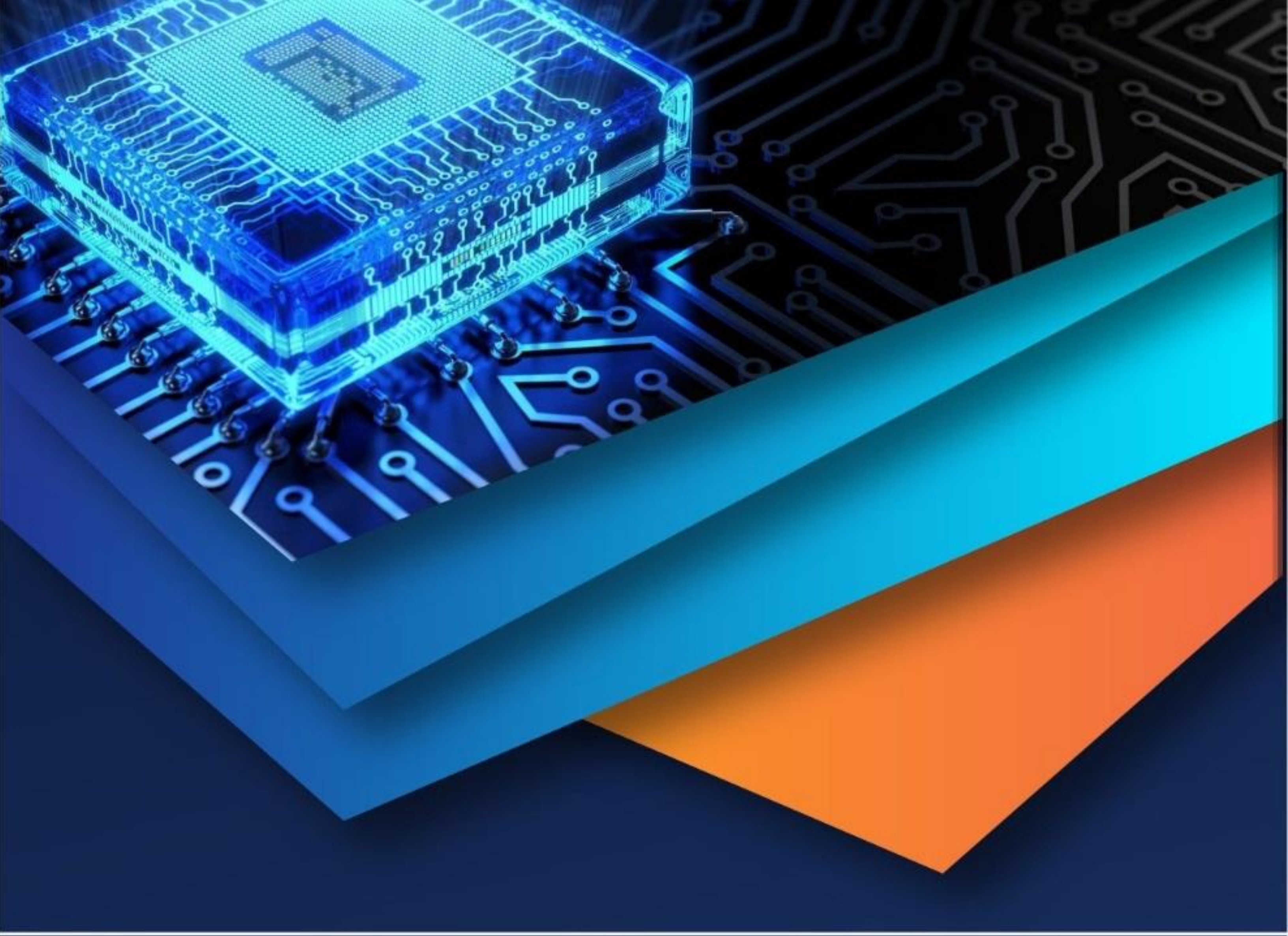

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