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A Study of Mechanical Properties of Structural Concrete incorporating Partial Replacement of Cement by GGBS and Natural Sand by Slag Sand

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Abstract*: The utilization of industrial waste produced by industrial processes has been focus of waste reduction research for economical, environmental and technical reasons. GGBS (Ground Granulated Blast Furnace Slag) and GBF Slag Sand is one such waste product of the iron manufacturing industry, whose use and production has increased many folds during last decades is used in this experimental work as alternative binder and filler materials for Ordinary Portland Cement (OPC) and River Sand respectively in concrete. M40 grades of concrete was considered for a water content (w/c) 0.4 and slag sand replaced by 0%,40%,50%&60% with river sand and GGBS replacements of 0%, 30%, 40%, 50% with cement to investigate the properties of compressive strength, split tensile strength, flexural strength of concrete mix. The strength of cube specimens varied from 49.60 N/mm^2 to 49.24 N/mm^2, The marginal strength of concrete mix (52.52N/mm^2) having 40% GGBS has shown high strength, similarly strength of concrete having only slag sand varied from 48.76 N/mm^2 to 43.77 N/mm^2, The marginal strength of concrete mix (49.71 N/mm^2) having 50% GGFS sand has shown high strength. When both are mixed, the mix having 40% GGBS and 50% Slag sand has shown high strength (58.41 N/mm^2).

***Keywords:* GBFS sand, GGBS, Compressive strength, Flexural strength, Split tensile strength and Flexural strength of RCC beams.**

I. INTRODUCTION

`Sustainable concrete is the main emphasis given to the present generation to produce concrete so as to overcome the scarcity of natural river sand and the environmental destruction (i.e. global warming) caused due to the emission of CO_2 during the hydration process of cement concrete. Hence, a concrete that can be sustained for a very long period of time and for the future generations to come is to be focused and stressed on. Concrete, that is most versatile building material used all over the globe in the construction industry has to be eco-friendly, economical and sustainable in terms of technical and non-technical aspects. Isayuksela [1], he presents investigation of how the usage of bottom ash (BA),

granulated blast furnace slag (GBFS), and combination of both of these materials as fine aggregate in concrete affects the concrete durability. Veena G. Pathan [2], made an experimental investigations carried out to evaluate effects of replacing GGBS as cement in concrete to with respect to workability, compressive strength. Concrete mix with 40% replacement of cement with GGBFS gave higher compressive strength. Mohammed Nadeem [2], Experimental investigation of using slag as an alternative to normal Aggregates (course and fine) in concrete. He present results of experimental investigations carried out to evaluate effects of replacing aggregate (coarse and fine) with that of slag on various concrete properties. Hemanth V. [4], experimental investigations were carried out to evaluate the effects of replacing the fly ash with cement and slag sand with river sand i.e. fly ash was kept constant as 30% and Slag sand was varied from 10% to 50% with 10% variation. The fresh and hardened concrete properties were evaluated. The optimum results were incorporated in to singly reinforced RCC beams with varying tensile reinforcement ratio to evaluate the flexural behaviour of beams.

II. EXPERIMENTAL PROGRAMME

A. Materials Used

In present work various materials is used with their respective properties namely: OPC 43 Grade, GGBS, Fine aggregates: Natural River sand and Slag sand (SS), Coarse aggregate, Super-plasticizer, and Water

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1) *Cement:* Ordinary Portland cement of 43 grades conforming to IS: 12269-1987 has been used. The physical properties of the cement obtained on conducting appropriate tests as per IS: 12269-1987.

TABLE 1: BASIC PROPERTIES OF CEMENT

Properties	Cement
Specific gravity	3.1
Standard consistency	31%
Initial setting time	38min
Final setting time	480min
Fineness	5.3%

2) *GGBS:* GGBS used in this experimental work is procured from JSW Cements. The physical were: Specific Gravity=2.90, Stadard Consistency= 34%, Initial setting time= 180 minutes as per IS: 4031- 1988
3) *Fine Aggregates:* Locally available clean river sand passing through IS-480 sieves have been used. The results of sieve analysis conducted as per the specification of IS: 383-1970. The fine aggregate was of Zone II, Fineness Modulus =2.60, Specific Gravity= 2.66 and loose bulk density of 1.47 g/cc
4) *Slag Sand:* The Granulated Blast Furnace Slag used in the present investigation was collected from JSW steel plant, district of Bellary. The tests on granulated blast furnace slag were carried out as per IS: 383-1970. Slag sand was of Zone 2. Fineness Modulus = 2.63, Specific gravity = 2.63, loose bulk density of 1.43 g/cc. aggregate considered is 20mm IS sieve passing and minimum size of aggregate considered is 12.5mm IS sieve passing. The results of sieve analysis conducted as per the specification of IS: 383-1970. Fineness Modulus =7.30, Specific Gravity= 2.60
5) *Water:* Clean potable water is used for casting and curing operation for the work. The water supplied in the campus is of the potable standard of pH value= 7.50 are used
6) *Super Plasticizer*: To improve the workability of fresh concrete sulphonated naphthalene based super plasticizer i.e., Conplast SP 430 was used supplied by FOSROC chemicals, 0.75% (max 2%) dosages was used to increase the workability of concrete.

B. Mix Proportion

Concrete mix design of M40 grade was designed conforming to IS: 10262-2009 is prepared and trial mixes were attempted to achieve workable concrete mix. Cubes of standard size 100x100x100mm, Beam of size 500x100x100mm and cylinders of diameter 100mm and height 200mm were casted and cured at room temperature. Cubes were tested at 7 and 28 days, cylinders and beams were tested for 28 days.

TABLE 2: CONCRETE MIX DESIGN

Unit of batch	Water (Litters)	Cement (Kgs)	FA (Kgs)	CA (Kgs)	Super plasticizer
Cubic meter of concrete	168	425	685	1127	3.2
Ratio of ingredients	0.4	1	1.61	2.65	0.75%

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TABLE 3: MIX PROPORTION

Mix	Cement in %	GGBS in %	NS in%	SS in%	slump
CM	100	00	100	00	100
M1	70	30	100	00	130
M2	60	40	100	00	140
M3	50	50	100	00	145
M4	100	00	60	40	75
M5	100	00	50	50	60
M6	100	00	40	60	55
M7	70	30	60	40	100
M8	70	30	50	50	130
M9	70	30	40	60	140
M10	60	40	60	40	60
M11	60	40	50	50	70
M12	60	40	40	60	100
M13	50	50	60	40	95
M14	50	50	50	50	100
M15	50	50	40	60	110

C. Fresh Concrete Properties

The test results showed that slump flow have improved as the GGBS content is increased the slump value is increased compared to the control mix. However all the concrete mixes were homogeneous and cohesive in nature also the slump had shear type of failure as the GGBS content was increased. No segregation and bleeding in any of the mixes were observed.

FIG 2: SLUMP TEST FOR FRESH CONCRETE

D. Hardened Concrete Properties

Compressive strength, splitting tensile strength and modulus of rupture of different mixes were determined.

1) Compressive Strength: The cubes of size 100mm×100mm×100mm are casted for various percentages of GGBS by (0%, 30%, 40% and 50%) and Slag sand (SS) 0%, 40%,50% & 60% The cubes are cured and tested for 7 and 28 days. Testing was made in 2000kN testing machine with loading rate of 140kg/cm/m^2. The average of 3 cubes for each curing and each replacement is noted down to get the compressive strength of concrete.

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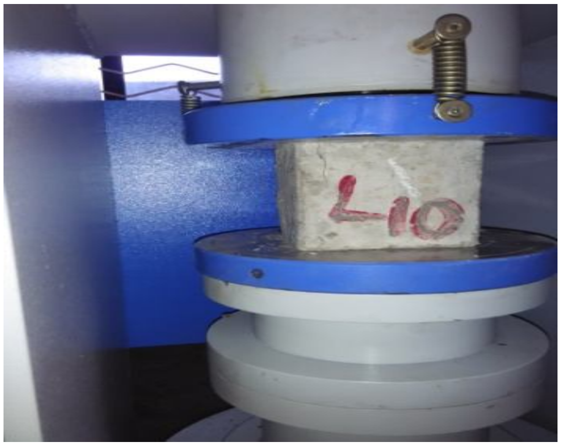


Fig 2: Compressive Strength Test

2) *Split Tensile Strength:* The splitting tensile strength is well known indirect test used for determining the tensile strength of concrete as it is one of the most important fundamental properties of concrete. Three cylinders of size 100mm diameter and 200m in length are casted for various percentages of GGBS by (0%, 30%, 40% and 50%) and Slag sand (SS) 0%, 40%,50% & 60% and cured for 28 days for each replacement of GGBS and Slag sand (SS). Testing was made in 2000kN testing machine at rate of loading as (1.2 to 2.4) (π/2) l*d, N/min. The average of three cylinders for each replacement is noted down to get the strength spilt tensile of concrete.


Fig 3: Split Tensilestrength Test

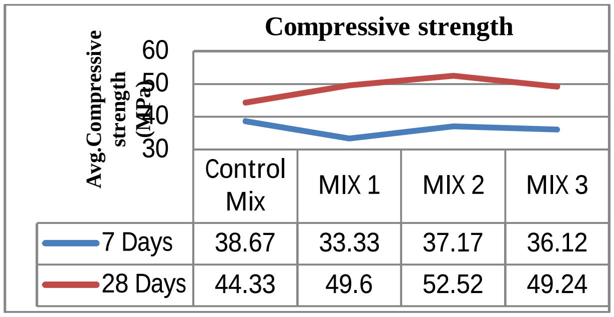
3) *Flexural Tensile Strength:* Flexural strength is defined as a materials ability to resist deformation under load. Three beams of size 100mm×100mm×500mm are casted for various percentages of GGBS by (0%, 30%, 40% and 50%) and Slag sand (SS) 0%, 40%,50% & 60% and cured for 28 days for each replacement of GGBS and Slag sand (SS). Testing was done under two point loading in flexural testing machine.


Fig 4: Flexuralstrength Test

III. RESULTS AND DISCUSSIONS

A. Compressive Strength

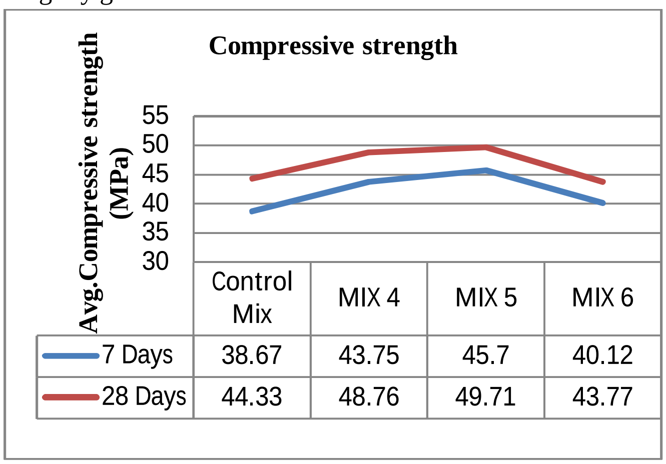
The results of compression are shown in graphical form in figure 5, 6 and 7.



	Control Mix	MIX 1	MIX 2	MIX 3
7 Days	38.67	33.33	37.17	36.12
28 Days	44.33	49.6	52.52	49.24

FIG 5: Compressive strength of GGBS concrete of 7th and 28th day.

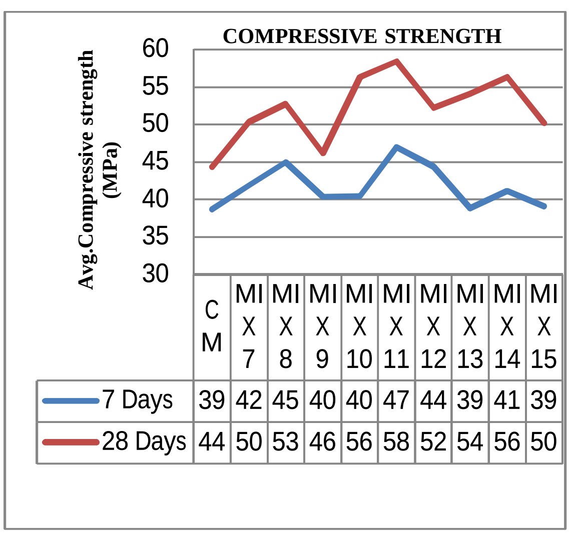
The graph represents variation in compressive strength for different proportions of GGBS. It can be seen that the mix M2 having 40% GGBS has higher strength, i.e. slightly greater then control mix.



	Control Mix	MIX 4	MIX 5	MIX 6
7 Days	38.67	43.75	45.7	40.12
28 Days	44.33	48.76	49.71	43.77

FIG 6: Compressive strength of Slag sand concrete of 7th and 28th day.

The graph represents variation in compressive strength for different proportions of Slag sand. Hear M5 mix having 50% slag sand has high strength.



	CM	MIX 7	MIX 8	MIX 9	MIX 10	MIX 11	MIX 12	MIX 13	MIX 14	MIX 15
7 Days	39	42	45	40	40	47	44	39	41	39
28 Days	44	50	53	46	56	58	52	54	56	50

FIG 7: Compressive strength of concrete with GGBS and Slag sand of various proportions.

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The graph represents variation in compressive strength for different proportions of Slag sand and GGBS. Hear mix M11 having 40% GGBS and 50% slag sand has high strength.

B. Split tensile strength.

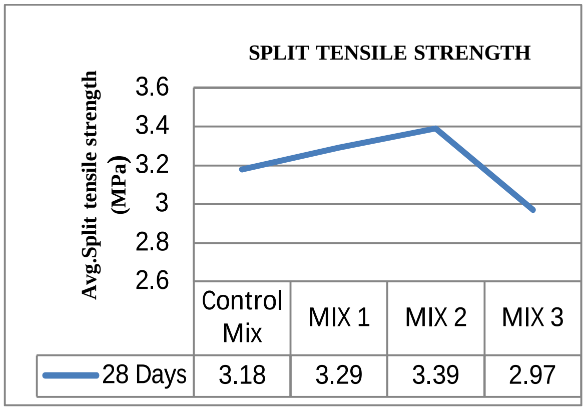

FIG 8:Split tensile strength of GGBS concrete of 7th and 28th day.

The graph represents variation in compressive strength for different proportions of GGBS. It can be seen that the mix M2 having 40% GGBS has higher strength.

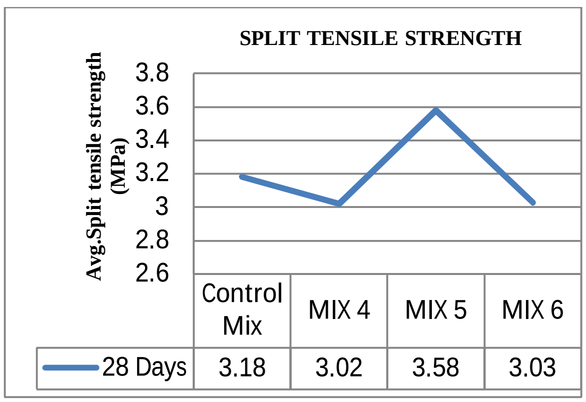

FIG 9: Split tensilestrength of Slag sand concrete of 7th and 28th day.

The graph represents variation in compressive strength for different proportions of Slag sand. Hear M5 mix having 50% slag sand has high strength.

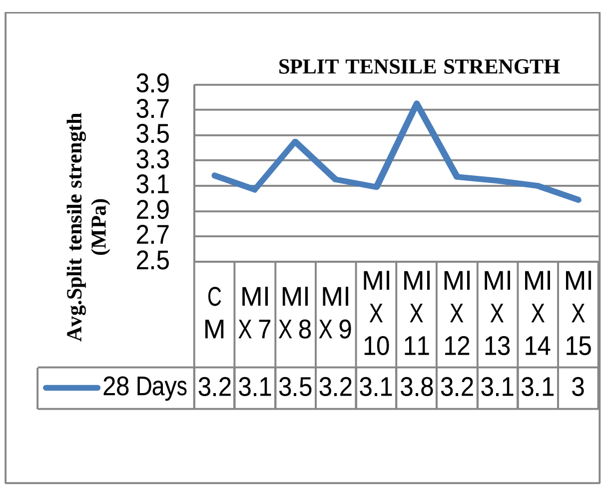

FIG 10: Split tensile strength of concrete with GGBS and Slag sand of various proportions.

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The graph represents variation in compressive strength for different proportions of Slag sand and GGBS. Hear mix M11 having 40% GGBS and 50% slag sand has high strength.

C. Flexural strength

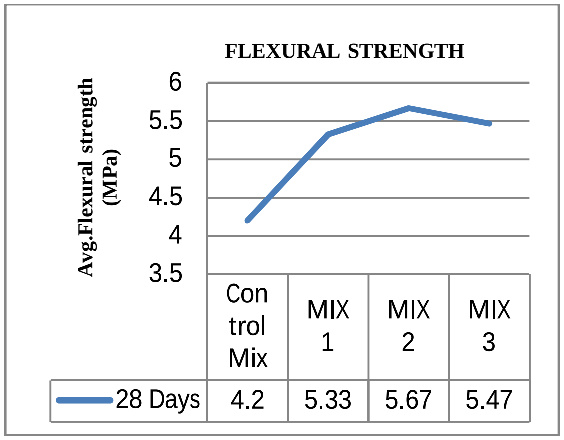

FIG 11:Flexural strength of GGBS concrete of 7th and 28th day.

The graph represents variation in compressive strength for different proportions of GGBS. It can be seen that the mix M2 having 40% GGBS has higher strength.

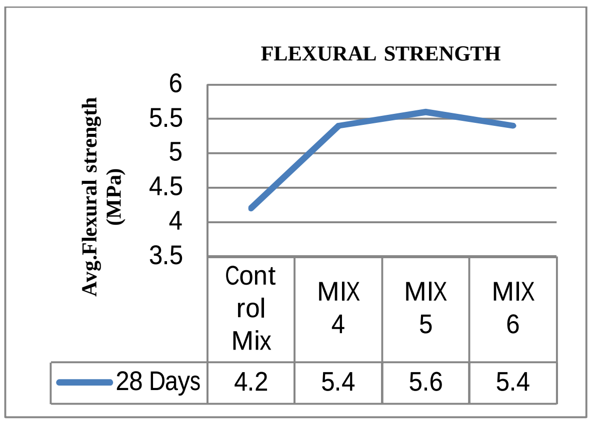

FIG 12: Flexural strength of Slag sand concrete of 7th and 28th day.

The graph represents variation in compressive strength for different proportions of Slag sand. Hear M4 mix having 50% slag sand has high strength.

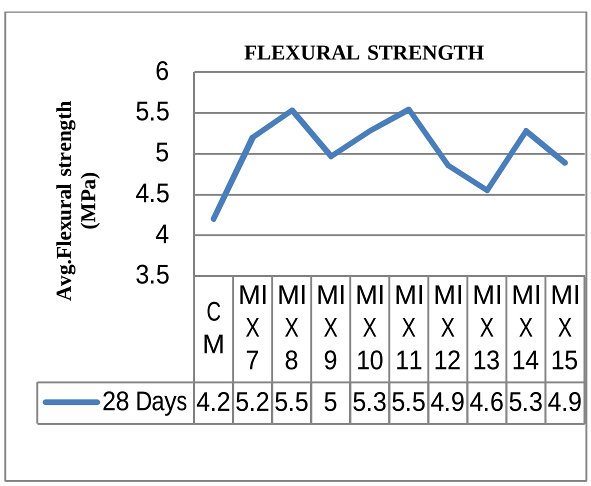

FIG 13: Flexural strength of concrete with GGBS and Slag sand of various proportions.

The graph represents variation in compressive strength for different proportions of Slag sand and GGBS. Hear mix M11 having 40% GGBS and 50% slag sand has high strength.

IV. CONCLUSION

A. Based on the Experimental Results Following Conclusion Were Made

The fresh concrete property (slump) varied from 100mm to 145mm and all the concrete mixes were homogeneous and cohesive in nature with no segregation and bleeding in any of the mixes. Also, the slump is improved as the GGBS content is increased with shear type of failure compared to the control mix. The results of the hardened concrete properties such as Compressive strength, split tensile strength and the flexural strength of the concrete mixes concluded that the mix having 40% GGBS (i.e. MIX- 2) was optimum at 28 days of curing period. The results of the hardened concrete properties such as Compressive strength, split tensile strength and the flexural tensile strength of the concrete mixes concluded that the mix having 50% Slag sand (i.e. MIX- 5) was optimum at 28 days of curing period. The results of the hardened concrete properties such as Compressive strength, split tensile strength and the flexural strength of the concrete mixes concluded that the mix having 40% GGBS and 50% Slag sand (i.e. MIX- was optimum at 28 days of curing period. The slag sand improves the density making it lighter compared to the conventional concrete. Also, the slag sand saves the natural resource i.e. natural river sand by 50% making a sustainable concrete. The use of GGBS and Slag Sand in the present research work reduces the cost by 15% making a concrete sustainable, economical, eco-friendly pertaining to the CO_2 emission due to heat of hydration by OPC and saving the natural resource i.e. natural river sand which is at scares forever.

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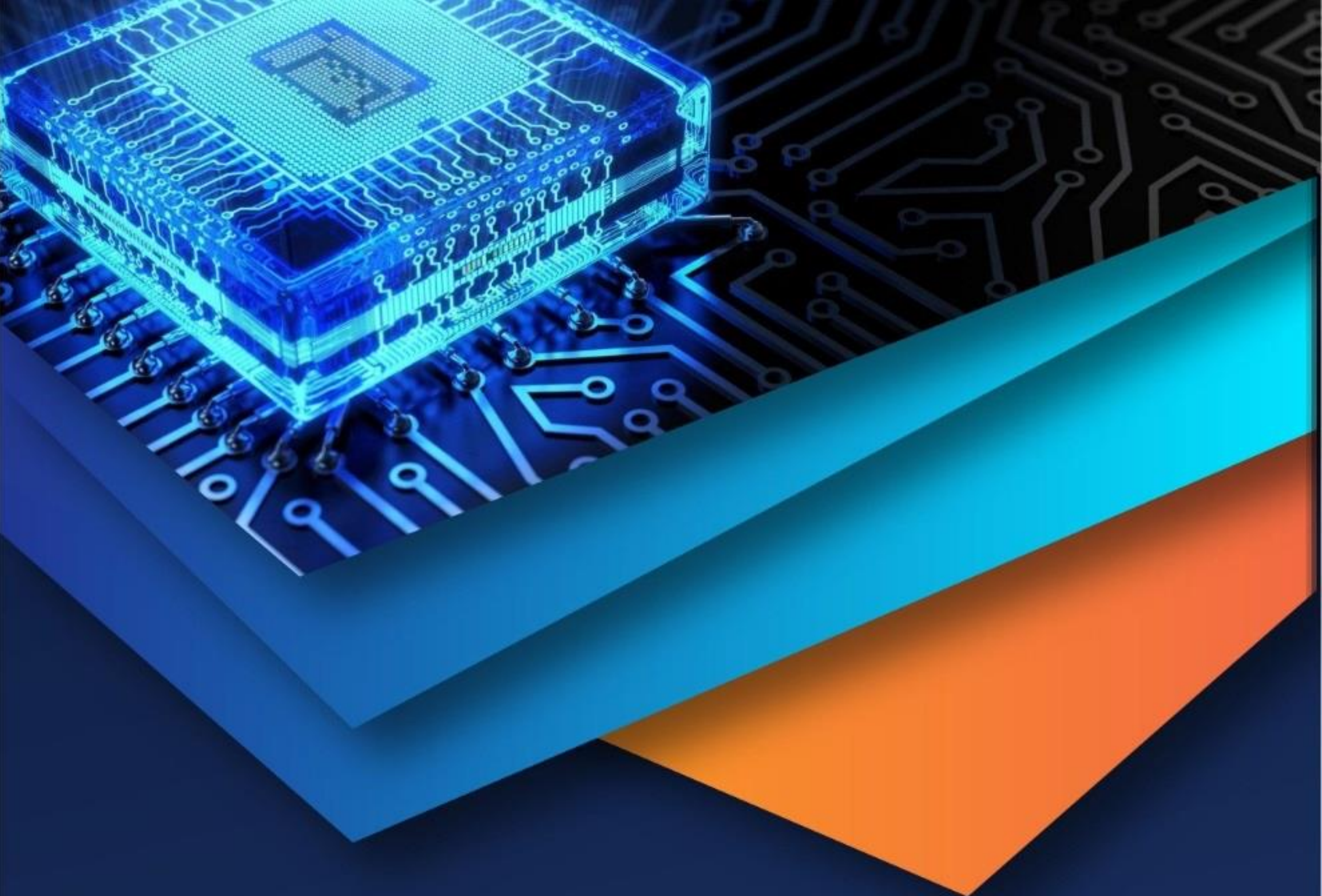

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