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Optimized Flyash in Concrete for Grade M15, M20, M25, M30, M35, M40 Using Portland Slag Cement

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***Abstract**: Earlier fly ash is being used in concrete with ordinary Portland cement. Optimization of fly ash in concrete by using Portland slag cement have obviously good impact on lowering the cost of concrete as well as consumption of by product and waste material fly ash and slag. Portland slag cement is already blended cement in which slag and clinker are grinded together by adding 65% slag .On one hand using the blended cement in concrete and on other hand using fly ash additionally will great effort to reduce the CO2 emission. This research paper optimized the quantity of fly ash in concrete of grade M15, M20, M25,M30,M35,M40. Portland slag cement confirming IS:455-1989 and high lime fly ash which is categorised as class C fly ash by ASTM, because of its high calcium content ,is used for the each trial mixes of concrete .High lime fly ash will act as binder material along with cement, also it's pozzolanic nature improves the durability of the concrete. In each mix for each grade of concrete , w/c ratio is kept lower side regarding the concern of maximum w/c ratio criteria as per IS 456-2000.The physical and chemical properties most importantly, its fineness, residue and lime content imparts vital role in water cement ratio and strength parameters in concrete.*

Several trial mixes is being prepared with varying amount of fly ash for each grade of concrete. For green concrete cohesiveness and workability criteria is maintained without changing the w/c ratio in each grade. To maintain the workable mix, super plasticizer is used. To assess the compressive strength of concrete 06 cubes of each batch,03 cubes for 7 days strength and 03 cubes for 28 days strength is casted, cured and tested. The results are being analysed and compared with standard concrete and conclusions made on how best the fly ash can be utilized to give optimum results. .
Keywords: Concrete grade, Portland slag cement, Class C fly ash, w/c ratio

I. INTRODUCTION

In last decades, there is lots of innovation in cement concrete technologies. Apart from the strength consideration, durability and economy have become important factors for deciding the concrete quality. Earlier, it was the thought to use the higher cement content means greater strength but durability of the structures is not adopted in true sense particularly the structures exposed to different climatic conditions. Now to use the supplementary cementitious material like fly ash is established concept to make cement concrete strong and durable at lower cost.

For several years fly ash has been used in varying proportions and compositions in cement concrete. Research indicates that there are still additional benefits to be gained if the concrete industry can further optimize its use in concrete. Fly ash is a by-product material of coal based power plant, which has been found to have numerous advantages for use in the concrete industry. The advantages includes the improved workability, reduced rate of hydration, cohesive mix without bleeding, better finished concrete and so lower voids, less permeable, increased ultimate strength, and ultimately durable structures. Fly ash produced will be of good quality if it contains low sulphur& very low unburnt carbon i.e. less loss on ignition. It is a pozzolanic material and has been classified into two classes, F and C, based on the chemical composition of the fly ash. The fly ash being used for this research contains significant amounts of lime i.e high lime fly ash and would be categorized as a Class C fly ash. In Portland slag cement, clinker as well as slag is composed of free lime and siliceous and aluminous materials (pozzolans), which in the presence of water, will chemically react with the calcium hydroxide released by the hydration process to form a cementitious paste that binds the inert materials in the concrete. Fly ash is also a pozzolanic material but with different amounts of the constituents. The fly ash being used for this study contains significant amounts of lime, which reacts with the pozzolans within itself forming (hydrated) calcium silicate gel or calcium aluminate gel (cementitious material) which bind the inert material together, making it self-cementing. All fly ash have a particle size ranging less than 0.075 mm. The fineness and lime content properties of the fly ash are of great concern since

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they will affect the water demand of the concrete; parameters which greatly affect the durability and strength of concrete respectively.

II. LITERATURE REVIEW

Many researchers gave their way to use the high amount of fly ash, to relieve the carbon footprint, to reduce the concrete cost and uses of wastage material fly ash.15%-60% of fly ash by cement replacement is allowed. It not only reduces the cement quantity but also act as filler material. Using fly ash as filler material is also the another research aspect. Research on using fly ash also says about the limitation of fly ash in different environment conditions, lower early strength, delay in setting etc**.** Summary of some research papers are mentioned here.

A. Literature on Optimizing the Use of Fly Ash in Concrete - Portland Cement

M Thomas presented optimization of the use of fly Ash in Concrete with Portland cement. He divided his work in two parts, the first one determines influence of high volume fly ash replacement of Portland cement on behaviour and properties of cement paste and mortar. The second part optimizes composition of concrete mix, in particular the granulometry of the cement-fly ash system in order to achieve maximal possible values of mechanical properties at high dosage of fly ash. The demand for concrete structures grows worldwide, which raises fears about sustainable development of Portland cement production. Its carbon footprint is relatively small compared to alternative building materials, but still it is not negligible. This argument together with lower cost and possibility of utilization of material, which would otherwise be disposed as waste, lead the research towards concrete with higher content of Portland cement replaced with fly ash.

B. Literature on Specifying Fly Ash for Use in Concrete

Karthik H. Obla, used fly ash in concrete has had a successful track record. The performance benefits fly ash provides to mechanical and durability properties of concrete have been well researched and documented in actual structures. Currently, fly ash is used in more than 50% of all ready mixed concrete placed in the United States, yet many design professionals continue to remain overly restrictive when it comes to using fly ash in concrete. This article addresses some optimal ways of specifying fly ash for use in concrete while ensuring that the desired concrete performance is achieved. Most of these recommendations form part of a larger NRMCA publication that should be released later in 2008. Project specifications for most commercial work in the United States are typically written as per American Institute of Architects Master Spec format.

C. Literature on Development of Statistical Models for Mixture Design of High-Volume Fly Ash Self-Consolidating Concrete

R. Patel, K. M. A. Hossain, M. Shehata, N. Bouzoubaa, and M. Lachemi worked on Self-consolidating concrete (SCC) in the fresh state is known for its excellent deformability, high resistance to segregation, and use, without applying vibration, in congested reinforced concrete structures characterized by difficult casting conditions. Such concrete can be obtained by incorporating either mineral admixtures such as fly ash (FA) or viscosity-modifying admixtures (VMA). The use of VMA has proved very effective in stabilizing the rheology of SCC, and recent researches are focused on the development of new, cheaper VMAs compared with currently available, costly commercial ones. Research to produce an economical SCC with desired properties was conducted over the last few years with the use of FA. In the present study, 21 statistically balanced concrete mixtures were investigated to minimize the use of high-range water-reducing admixtures (HRWRA) and to optimize the use of fly ash in SCC. The minimum use of HRWRA and optimum use of FA were desired in this study. Four independent variables such as total binder content (350 to 450 kg/m3), percentage of FA as cement replacement (30 to 60% by mass), percentage of HRWRA (0.1 to 0.6% by solid mass), and water-binder ratio w/b (0.33 to 0.45) were used for the design of SCC mixtures. The fresh concrete properties were determined from slump flow, V-funnel flow, filling capacity, bleeding, air content, and segregation tests. The mechanical properties and durability characteristics of SCC such as compressive strength, freezing-and-thawing resistance, rapid chloride permeability, surface scaling resistance, and drying shrinkage were determined to evaluate the performance of SCC. Four statistical models to predict the slump flow, 1-day and 28-day compressive strength, and the rapid chloride permeability of SCC were developed and their performances were validated. The models can be used as economical tools for the optimized design of FA SCC mixtures with desired properties in practical applications.

D. Literature on fly ash in Concrete

G R Bharsakle uses the fly ash in concrete at levels ranging from 15% to 25% by mass of the cementitious material component. The actual amount used varies widely depending on the application, the properties of the fly ash, specification limits, and the geographic location and climate. Higher levels (30% to 50%) have been used in massive structures (for example, foundations and dams) to control temperature rise. In recent decades, research has demonstrated that high dosage levels (40% to 60%) can be used in structural applications, producing concrete with good mechanical properties and durability (Marceau 2002).Increasing the amount of fly ash in concrete is not without short comings .At high levels problems may be encountered with extended set time and slow strength development, leading to low early-age strengths and delays in the rate of construction. These drawbacks become particularly pronounced in cold-weather concreting. Also, the durability of the concrete may be compromised with regards to resistance to deicer-salt scaling and carbonation. For any given situation there will be an optimum amount of fly ash that can be used in a concrete mixture which will maximize the technical, environmental, and economic benefits of fly ash use without significantly impacting the rate of construction or impairing the long term performance of the finished product. The optimum amount of fly ash will be a function of wide range of parameters and must be determined on a case-by-case basis.

III. PROBLEM IDENTIFICATION

Most of the works on optimization of fly ash in cement concrete is being carried out using Ordinary Portland Cement as binder. There are recommendations for the high dosage of fly ash in mass concreting, to reduce the hydration. There are no guidelines, particularly to prepare a trial mixes of different grades of concrete with the high doses of fly ash. Also using the fly ash in cement concrete have had shortcomings like delay in setting, slow rate of construction.

Secondly the durability of the structures can't be compromised on behalf of lowering the cost of concrete with high dosage of fly ash. So it is followed the criteria for lower w/c and target strength as compressive strength of each grade as per recommendation in IS 456-2000.

IV. METHODOLOGY AND GOVERNING EQUATION

A. Methodology

Several trial mixes is being prepared with varying amount of fly ash for each grade of concrete. For green concrete cohesiveness and workability criteria is maintained without changing the w/c ratio in each grade. To maintain the workable mix, super plasticizer is used. To assess the compressive strength of concrete 06 cubes of each batch, 03 cubes for 7 days strength and 03 cubes for 28 days strength is casted, cured and tested. The results are being analysed and compared with standard concrete and conclusions made on how best the fly ash can be utilized to give optimum results.

B. Materials and Testing

1) *Fly Ash:* High Lime fly ash obtained from a local power plant was used in this project. The specific gravity of the fly ash used was 2.71 g/cc. This fly ash had a significant amount of lime at 21.35% and a sulphur trioxide content of 5.19 %, which exceeds the ASTM C618 limits for Class C fly ashes for use in concrete. This project has focused more on the positive utility of the high lime fly ash to reduce the clinker factor in cement concrete and somehow used to replace the river sand by fly ash, assumed to act as filler material.
2) *Portland Slag Cement (PSC):* PSC is blended cement. It is the most suitable cement for Infrastructure Projects because of its high flexural strength. Maximum strength, low risk of cracking, improved workability, and superior finish are the advantages of PSC. Portland Slag Cement (PSC) is manufactured by either inter-grinding in the Portland cement clinker, Gypsum & Granulated Slag or blending the Ground Granulated Blast Furnace Slag (GGBS) with Ordinary Portland Cement by means of mechanical blenders. It confirms the IS: 12089 standards for producing PSC. It is created with a combination of 60-65% slag, 30% –37% clinker, and 3-5% gypsum. PSC has been used as the most suitable cement for concrete pavements, mass concrete applications, high performance or high strength concrete, structures and foundations, pre-cast concrete such as pipe & block, concrete exposed to sea water and marine application.
3) *Aggregate:* As coarse aggregate 20mm size and 10 mm size aggregate is being used. It is crushed stone. River sand of zone II is used as fine aggregate. It's source is Mahanadi River. All aggregates confirming the criteria of IS 383, along with requirements of IS 2386.
4) *Admixture:* To maintain the required workability of the green concrete up to the pouring point of the structure, super plasticizer is used to maintain the slump 80mm-110mm after 01 hour.

C. Compressive Strength

The concrete trial mixes was prepared using the recommended guidelines as per IS 10262. To recommend the optimized fly ash for a particular grade, 28 days compressive strength will final criteria. The different trials for the particular grade of concrete, which achieves the target strength at maximum amount of fly ash will an optimized trial. Target strength for particular grade of concrete will consider the standard deviation mentioned in table 8 of IS 456:2000.Water/cementitious ratio for each trials of particular Grade is being maintained, following the criteria of IS 456:2000.The concrete mixes would be made using PSC Cement and maximum size of aggregate is 20mm.They were prepared and batched by weight with varying percentages of fly ash added to replace varying percentages of the cement. The Concrete cubes casted for 7days and for 28 days will be tested to know the Compressive strength of each trial, following the criteria of IS 516.

D. Formulae for target strength and Mix calculations of concrete

According to IS 456:2000, the target strength of the concrete mixture is defined as: Target strength = fck + 1.65 s, where s is the standard deviation. Here,

fck =characteristic compressive strength at 28 days in N/mm^2

s=standard deviation; 3.5 N/mm^2 for M10&M15

; 4.0 N/mm^2 for M20,&M25

; 5.0 N/mm^2 for M30, M35 & M40

Target strength =20.77 N/mm^2, 26.60 N/mm^2,31.60 N/mm^2 ,38.25 N/mm^2,43.25 N/mm^2,48.25 N/mm^2 for M15, M20,M25,M30,M35&M40 respectively.

According to IS 10262:2009, Mix calculations per unit volume of concrete is as follows: For M15 grade

a. volume of concrete =1m^3

b. volume of cement =Mass of cement/(specific gravity of cement×1000)
=300/(3.15×1000)
=0.09 m^3

c. volume of water =Mass of water/(specific gravity of water×1000)
=163/1000
=0.163 m^3

d. volume of chemical admixture = Mass of chemical admixture/(specific gravity of admixture×1000)
=3/(1.14×1000)
=0.003 m^3

e. volume of all in aggregate =[a-(b+c+d)]
=0.744 m^3

f. mass of coarse aggregate =e× Volume of coarse aggregate× Specific gravity of coarse aggregate×1000
=0.744×0.53×2.73×1000
=1071 kg

g. mass of fine aggregate =e× Volume of fine aggregate× Specific gravity of fine aggregate×1000
=0.744×0.47×2.46×1000
=862 kg

V. RESULT

There are following trial mixes for each grade separately and the compressive strength in 7 days and in 28 days.

TABLE I

CONCRETE MIXES (DESIGN STRENGTH -15 MPA),W/C=0.54

Parameter	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
Fly Ash (%)	0	15	30	40	45	50
Water (litre)	163	163	163	163	163	163
Cement (kg)	300	255	210	180	165	150
Fly ash (kg)	0	45	90	120	135	150
20 mm(kg)	664	670	676	684	689	695
10 mm(kg)	407	410	415	417	422	426
Fine aggregate (kg)	862	852	842	832	822	812
Admixture	1%	0.8%	0.7%	0.53%	nil	nil

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TABLE II
COMPRESSIVE STRENGTH OF CONCRETE MIXES FOR M15 (TARGET STRENGTH -20.77 MPA)

Compressive strength (MPa)	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
At 7 Days	16.92 17.85 19.23	14.26 12.29 11.23	10.96 10.35 10.32	11.09 11.22 11.25	9.32 10.11 10.85	8.63 9.25 10.11
Average Strength (At 7 Days)	18.00	12.59	10.54	11.19	10.09	9.33
At 28 days	25.56 24.28 25.87	23.35 24.15 23.79	21.54 22.09 21.38	20.08 21.93 21.54	18.78 19.34 16.55	15.76 13.78 12.84
Average Strength (At 28 days)	25.24	23.76	21.67	21.18	18.22	14.13

TABLE III
CONCRETE MIXES (DESIGN STRENGTH -20 MPA),W/C =0.38

Parameter	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
Fly Ash (%)	0	15	30	40	45	50
Water (litre)	146	146	146	146	146	146
Cement (kg)	380	323	266	247	228	209
Fly ash (kg)	0	57	114	133	152	171
20 mm(kg)	751	757	764	771	778	785
10 mm(kg)	353	357	360	363	366	369
Fine aggregate (kg)	748	738	728	718	708	698
Admixture	1.1%	.9%	.9%	0.84%	0.5%	nil

TABLE IV
COMPRESSIVE STRENGTH OF CONCRETE MIXES FOR M20 (TARGET STRENGTH -26.6MPA)

Compressive strength (MPa)	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
At 7 Days	25.67 24.98 23.18	23.63 24.76 23.05	21.28 20.62 21.53	19.34 18.58 19.34	18.73 18.56 17.46	15.63 14.25 12.11
Average Strength (At 7 Days)	24.61	23.81	21.14	19.09	18.25	14.00
At 28 days	34.67 33.89 36.35	32.67 33.28 31.57	30.46 30.27 29.87	28.38 28.12 27.34	26.65 27.35 26.72	23.11 20.43 20.56
Average Strength (At 28 days)	34.97	32.51	30.2	27.95	26.91	21.37

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TABLE V

CONCRETE MIXES (DESIGN STRENGTH -25 MPA),W/C=0.39

Parameter	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
Fly Ash (%)	0	15	20	25	30	35
Water (litre)	158	158	158	158	158	158
Cement (kg)	400	340	320	300	280	260
Fly ash (kg)	0	60	80	100	120	140
20mm(kg)	787	794	801	808	815	822
10mm(kg)	337	340	343	346	349	352
Fine aggregate (kg)	718	708	698	688	678	668
Admixture	1.2%	0.9%	0.9%	0.80%	0.7%	0.4%

TABLE VI

COMPRESSIVE STRENGTH OF CONCRETE MIXES FOR M25 (TARGET STRENGTH – 31.6MPA)

Compressive strength (MPa)	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
At 7 Days	27.86 27.55 30.23	25.04 24.45 25.89	23.65 23.12 22.43	22.96 22.45 23.28	21.96 23.05 22.94	18.45 19.57 21.12
Average Strength (At 7 Days)	28.55	25.13	23.07	22.90	22.65	19.71
At 28 days	38.45 39.56 38.23	36.23 35.43 37.02	35.75 35.26 34.78	34.56 33.12 33.67	33.27 32.35 32.87	28.34 25.78 28.12
Average Strength (At 28 days)	38.75	36.23	35.26	33.78	32.83	27.41

TABLE VII

CONCRETE MIXES (DESIGN STRENGTH -30MPA),W/C=0.37

Parameter	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
Fly Ash (%)	0	15	20	25	30	35
Water (litre)	160	160	160	160	160	160
Cement (kg)	440	374	352	330	308	286
Fly ash (kg)	0	66	88	110	132	154
20 mm(kg)	730	734	737	740	744	748
10 mm(kg)	313	314	316	318	319	320
Fine aggregate (kg)	685	680	675	670	665	660
Admixture	1.1%	1%	0.80%	0.80%	0.7%	0.7%

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TABLE VIII

COMPRESSIVE STRENGTH OF CONCRETE MIXES FOR M30 (TARGET STRENGTH -38.25 MPA)

Compressive strength (MPa)	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
At 7 Days	36.45 37.85 36.33	32.56 32.32 33.45	26.96 30.35 30.32	27.44 28.04 27.78	24.57 26.38 23.45	22.86 20.35 24.26
Average Strength (At 7 Days)	36.74	32.78	29.21	27.75	24.80	22.49
At 28 days	44.35 43.76 42.65	40.32 41.45 42.34	38.94 39.60 40.72	36.65 35.10 36.44	35.84 34.65 33.24	33.12 32.54 31.08
Average Strength (At 28 days)	43.59	41.37	39.75	36.06	34.58	32.25

TABLE IX

CONCRETE MIXES (DESIGN STRENGTH -35MPA),W/C=0.33

Parameter	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
Fly Ash (%)	0	15	20	25	30	35
Water (litre)	160	160	160	160	160	160
Cement (kg)	480	408	384	360	336	312
Fly ash (kg)	0	72	96	120	144	168
20 mm(kg)	806	809	813	822	820	824
10 mm(kg)	313	315	316	312	319	320
Fine aggregate (kg)	658	653	648	643	638	633
Admixture	1.2%	1%	0.9%	0.8%	0.6%	0.6%

TABLE X

COMPRESSIVE STRENGTH OF CONCRETE MIXES FOR M35 (TARGET STRENGTH -43.25MPA)

Compressive strength (MPa)	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
At 7 Days	37.89 37.85 39.23	35.04 33.67 34.56	32.96 30.54 33.32	32.37 30.37 30.38	30.56 29.78 30.85	26.63 29.25 27.11
Average Strength (At 7 Days)	38.32	34.42	32.27	31.04	30.40	27.66
At 28 days	46.76 45.93 47.82	46.86 45.04 46.89	44.37 45.50 44.05	40.99 38.03 39.00	37.65 36.45 35.25	32.44 31.67 33.56
Average Strength (At 28 days)	46.84	46.26	44.64	39.34	36.45	32.56

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TABLE XI
CONCRETE MIXES (DESIGN STRENGTH -40MPA),W/C=0.30

Parameter	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
Fly Ash (%)	0	10	15	20	25	30
Water (litre)	153	153	153	153	153	153
Cement (kg)	510	459	433	408	383	357
Fly ash (kg)	0	51	77	102	127	153
20 mm(kg)	829	833	837	840	844	847
10 mm(kg)	323	324	325	327	328	330
Fine aggregate (kg)	644	639	634	629	624	619
Admixture	1.2%	1%	1%	0.7%	0.5%	0.5%

TABLE XII
COMPRESSIVE STRENGTH OF CONCRETE MIXES FOR M40 (TARGET STRENGTH-48.25 MPA)

Compressive strength (MPa)	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
At 7 Days	39.65 38.66 39.35	38.79 37.95 37.56	39.02 36.18 35.29	34.44 32.98 31.79	30.45 29.78 30.02	27.89 28.25 26.22
Average Strength (At 7 Days)	39.22	38.1	36.83	33.07	30.08	27.45
At 28 days	49.75 51.82 50.37	48.73 49.22 48.34	44.08 44.28 45.00	42.06 43.37 42.56	38.98 39.23 40.56	37.88 36.23 37.34
Average Strength (At 28 days)	50.65	48.76	44.45	42.66	39.59	37.15

VI. CONCLUSION

In trial mixes of each grade, 06 trials are being performed. First trial of each grade is containing the quantity of Portland slag cement, which is being used by mass concrete users. On the basis of quantity of Portland slag cement used in 1st trial, different percentage of fly ash is added on further trials. The trials with maximum quantity of fly ash, which achieve the target strength for a particular grade, is the optimized percentage of fly ash for that grade of concrete. As from the results, the optimized quantity of fly ash is 40% for M15 & M20,25% for M25,20% for M25 & M30 and 10% for M40.It is clear from the results, as we move for the higher grade optimized percentage goes to lower.

The optimised quantity of fly ash will differ if the physical and chemical properties of fly ash and PSC cement differs, like different slag content of PSC, different fineness and lime content of fly ash. Also optimized percentage will differ if water cementitious selection for any grade will differ. Even if all the changeable parameter is varying the optimised percentage will vary in range of 0-5%.This work on optimization of fly ash in concrete by using the blended cement as PSC is helpful to lower the cost of concrete, CO_2 emissions but not on the cost of strength and durability parameter.

VII. FUTURE SCOPE

In today's scenario vital research on concrete technology is pursuing. To lower the cost impact and to save our environment is prime motivation; necessarily clinker factor should be minimized to reduce the CO_2 emissions. The future scope of using the blended cement in concrete manufacturing shows the way. It will contain clinker ,slag and fly ash in an effective proportion to fulfil the requirement.

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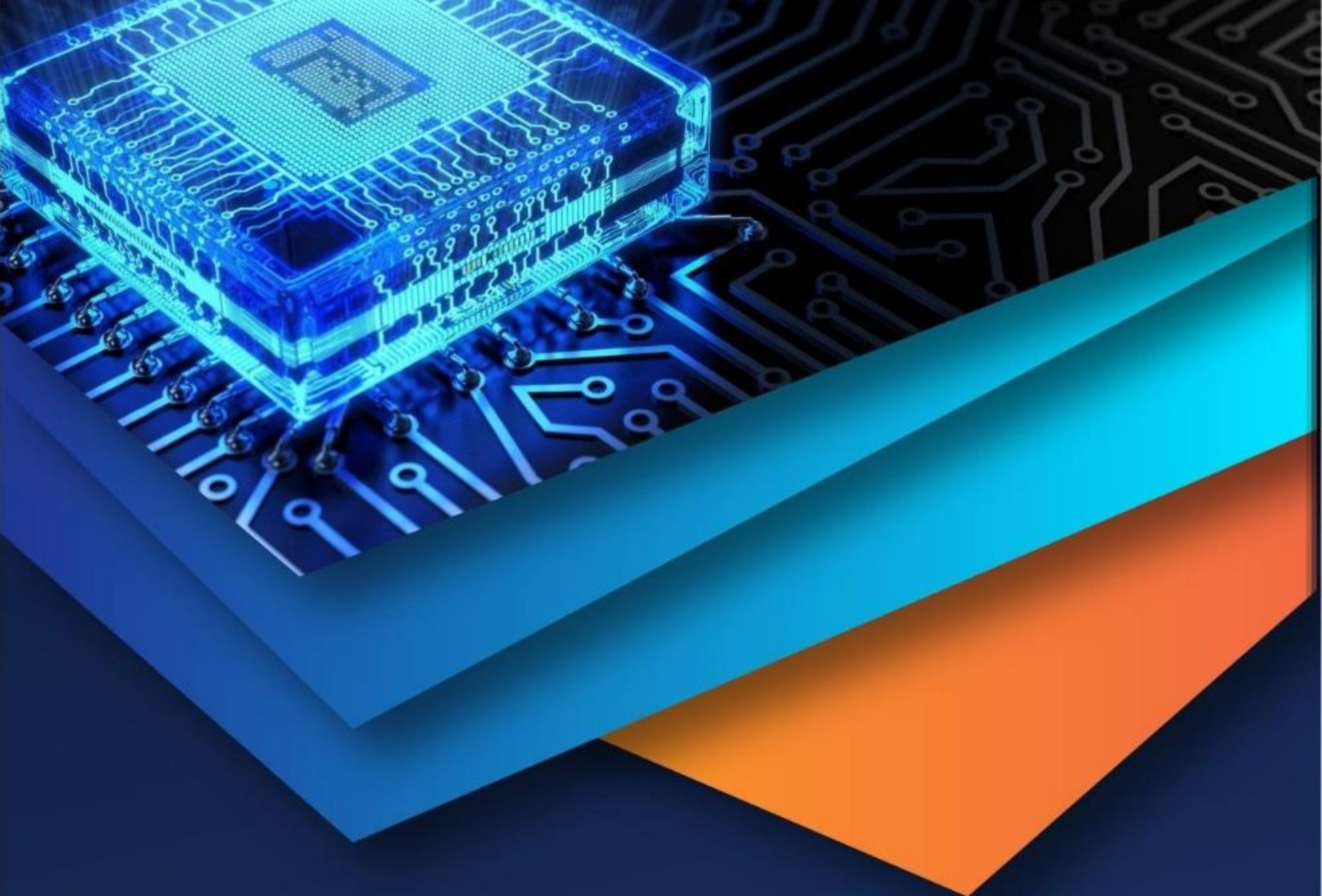

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