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Development of Self-Compacting Concrete using Composite Cement with Partial Replacement of Potable Water with Treated Wastewater

Abhishek Kumar[1], Sayantan Ghosh[2], Hemant Sood[3]
[1]ME student at Civil Engineering Department NITTTR Chandigarh, 160019 India
[2]Ph.D student at Civil Engineering Department NITTTR Chandigarh, 160019 India
[3]Professor and Head, Civil Engineering Department NITTTR Chandigarh, 160019 India

Abstract: Due to the rapid urbanization in the world, the groundwater level in this continent is decreasing by days. In addition, sea levels are rising due to global warming. For this reason, potable water resources are depleting at an alarming rate in many countries. This trend is observed not only in India, but all over the world. The study discusses the vitality of treated domestic and industrial wastewater that can be used for concreting at construction sites which can help to eliminate the potable water problem. Different physical and chemical properties of the industrial and domestic treated wastewater will be identified. Its effect on the properties of self-compacting concrete was examined in this study. The main objective of this research was to provide a durable and effective solution to the water scarcity. SCC can help mitigate these types of problems in such harsh jobsite environments. Preferably the development of concrete mixes, where pouring and compacting is less dependent on available labor at a particular site, can help improve the actual quality of concrete in the structure and thereby its durability. It is therefore an important driving force in the development of self-compacting concrete. This thesis demonstrates an opportunity to use treated wastewater as an alternative to potable water in concrete. This trial investigation has been carried out at SCC with composite cement having different compositions. Potable water was replaced with treated wastewater by 50% and 100%. Using these additions M30 and M35 grade SCC were casted. The properties of fresh concrete were determined using the slump flow, T500mm test, the V-funnel test and the L-Box test. In addition, this study highlights the average compressive strength of cubes, tensile strength at fracture and flexural strength of concrete. From the above results of fresh concrete and hardened concrete properties, it can be inferred that treated wastewater can be used as a substitute of potable water.
Keywords: Potable water, Treated wastewater, SCC, slump flow, V-funnel, L-Box, Compressive strength, Split tensile strength, Flexural strength.

I. INTRODUCTION

It has been perceived that with water, various mass scale plans are being adopted to utilize the resources which have not been productive as such. Present-day technology has led to the discovery of high-performance concrete with provides greater load resisting qualities. Additionally, be replacing Ordinary Portland cement with fly ash or ground granulated blast furnace slag (GGBFS) in the mix, the produced concrete. Researchers by practical observations, reported that in-situ concreting is highly affected by insufficient and improper compaction especially while concreting in congested reinforcement areas. Also, compaction, requires better quality of shuttering, stages, scaffoldings etc. in order to resist the additional forces derived due to devices used for compaction. Also in some cases, compaction requires for heavy reinforcement which becomes problematic with traditional concrete to fill that section completely and hence it was to discover a concrete which possesses relevant passing and filling tendency and also serve the purpose of adequate durability. This concrete was termed as Self-compacting concrete (SCC).

II. LITERATURE REVIEW

Bertil Persson [1] et al; Experimental and numerical study, on mechanical properties, such as strength, shrinkage, modulus of creep of self-compacting concrete (SCC) and corresponding properties of normal compacting concrete were thoroughly studied. This study included, eight mix proportions of air-cured or sealed specimens with water-binder ratio (w/b), varying b/w 0.24 - 0.80. Half of the mixes studied were based on normal compacting concrete. Age at loading, the concretes in creep were studied varied in range 2 and 90 days. Four different stress to strength levels were studied. Results show that shrinkage, elastic modulus and creep of SCC didn’t significantly affected from corresponding properties of normal compacting Concrete.

III. MATERIALS AND METHODS

A. Materials

The various materials used in this research are accomplished as per Indian standards codes.

1) *Cement:* In this research work Ordinary Portland cement of 43 grade Ultra Tech cement confirming to BIS 269-2015 obtained from Chandigarh sector 7. Its physical properties are in accordance to BIS 4031 are described in table 1.

Table 1. Physical Properties of Cement

Description	Test Results	Requirements as per IS269:2015
Initial Setting time (minute)	34	30 (minimum)
Final Setting time (minute)	310	600 (maximum)
Specific Gravity	3.13	-

2) *Fly Ash*: This is the bi-product of burned pummelled coal in thermal power plant and industries that uses coal. Effective use of pulverized fuel ash in production and partial replacement of cement, as an additive in cement, cement mortar and concrete, pozzolan lime mixture and products such as fly ash, lime brick, concrete blocks, asbestos cement products, etc., have been established in the country. India's pulverized fuel ash investigations have shown a larger scope for their use as building materials.
3) *GGBFS:* It is obtained by rapid quenching of the molten ash from the furnace with the help of water or stream and air. During the course of this process, the slag gets fragmented and transmute into amorphous granules.
4) *Treated Wastewater:* The treated wastewater samples used in this investigation was obtained from the Municipal Sewage treatment plant near 3BRD industrial area II, Chandigarh. The capacity of this treatment is 50 MLD and employs a sequencing batch reactor process for treating wastewater. The laboratory tests on the treated wastewater were carried out as per BIS 3025. The result are being tabulated under table 2.

Table 2. Test results on both treated Wastewater and potable water

Parameters	Potable Water (mg/l)	Treated Wastewater (mg/l)
pH	7.3	6.96
DO	7.47	6.92
COD	9	248
BOD	4	177
TDS	190	638
Sulphate Content	23.73	39.49
Chloride Content	17.8	138
Acidity	-	5.9

5) *Superplasticizer:* BASF MasterEase 3504 was used in the experimental investigation. The MasterEase 3504 is designed to impart exceptional rheological properties to fresh concrete. It improves considerably the placing and finishing of concrete. It is vastly used for self-compacting concrete that requires low viscosity, long workability retention and high compressive strength.

B. Mix Proportion Used

The experimentation was divided into two segment. In the first segment, SCC was prepared using treated wastewater as partial replacement i.e. 50% of potable water. In the second segment, SCC was prepared using treated wastewater as full replacement i.e. 100% of potable water. PT30C and PT30R indicates partially replaced potable water with treated wastewater of Case 1 and case 2 of grade M30. Similarly FT30C and FT30R indicates fully replaced potable water with treated wastewater of Case 1 and case 2 of grade M30 and same applicable for M35 grade in nomenclature. Each mixes proportioning are as per BIS 10262-2019 and are tabulated in the table 3 and table .4.

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Case 1 – OPC65%+FLA15%+GGBFS20%
Case 2 – OPC85%+FLA15%
OPC- Ordinary Portland Cement
FLA- Fly Ash
GGBFS- Ground Granulated Blast Furnace Slag
SP- Super-plasticizer
CA- Coarse Aggregate
FA- Fine Aggregate
W/C- Water/Cement

Table 3. SCC Mix Proportioning for M30

Mix	Cement kg/m^3	FLA kg/m^3	GGBFS kg/m^3	W/C	Potable water litre/m^3	Treated waste water litre/m^3	SP kg/m^3	FA kg/m^3	CA kg/m^3
PT30C	352.85	81.4	108.6	0.35	85	85	6.5	754	860
PT30R	461.42	81.4	0	0.35	85	85	7.3	758	864
FT30C	352.85	81.4	108.6	0.35	0	190	6.5	754	860
FT30R	461.42	81.4	0	0.35	0	190	7.3	758	864

Table 4. SCC Mix Proportioning for M35

Mix	Cement kg/m^3	FLA kg/m^3	GGBFS kg/m^3	W/C	Potable water litre/m^3	Treated waste water litre/m^3	SP kg/m^3	FA kg/m^3	CA kg/m^3
PT35C	390	90	120	0.32	85	85	7.2	724	848
PT35R	510	90	0	0.32	85	85	8.1	721	845
FT35C	390	90	120	0.32	0	190	7.2	724	848
FT35R	510	90	0	0.32	0	190	8.1	721	845

C. *Methods*

1) *Properties of Fresh Concrete:* Evaluation of the workability of self-compacting concrete mix can be divided into three categories that are as follow:
   a) Evaluation based on filling ability,
   b) Evaluation based on passing ability, and
   c) Evaluation based on segregation.

Table 5. BIS Classification for SCC (BIS 10262:2019)

Test	Property	Class	Range
Slump flow Test	Filling Ability	SF1	550 mm to 650 mm
		SF2	660 mm to 750 mm
		SF3	760 mm to 850 mm
V-Funnel Test	Viscosity	V1	≤ 8 sec
		V2	8 to 25 sec
L-Box Test	Passing Ability	-	0.8 to 1.0

d) *Slump Flow Test:* The slump test is the most simple and rapid test used to evaluate the deformability of SCC in the absence of obstacles. The above test measures the filling ability by measuring the horizontal flow diameter in mm and also the viscosity of mix by measuring the time needed for SCC to reach 500 mm flow (T_{500mm}). The segregation resistance in this test can be checked visually. Such is the simplicity of this test that can be done either on site or in the laboratory with inverted or upright Abram's cone. Slump flow test fall under SF2 category which is used for normal application.

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e) *V-Funnel Test:* The V-funnel test measure the ease of flow of concrete. Shorter flow time indicates greater flow ability. High value time is also related with other properties of concrete like low workability and high internal friction between particles. The inverted cone shape restricts the flow and prolonged flow time may give some indication of the susceptibility of the mix to blocking. From the V-Funnel test it fall under V2 category which show thixotropic effect helps in limiting pressure of foam work and improving segregation resistance.

f) *L-Box Test:* L-Box test is used to assess both filling and passing ability of SCC or in other words the ability of concrete to pass through reinforced bars without blocking or segregation. After filling the vertical column of the L-Box apparatus, the stoppage gate is lifted to allow SCC to flow into the horizontal part after passing through the rebar obstructions. Two measurements are taken H1 and H2 which represent the heights of concrete at the beginning and the end of the horizontal section, respectively. The ratio H2/H1 represents the filling ability and typically this value should be in the range of 0.8 to 1.0. All the design mixes satisfy the required criteria.

2) *Properties of Hardened Concrete:* A proper time schedule for testing of hardened SCC specimen was maintained in order to ensure proper testing on the due date. The specimens were tested using standard testing procedures.

a) *Compressive Strength Test:* Cubes specimen of size 150 mm × 150 mm × 150 mm were casted for compressive strength as per Bureau of Indian standards BIS 516. Compressive strength tests for cubes were carried out at 7, 14 and 28 days. Three specimens, preferably from different batches, were made available for testing at selected age. Tests was conducted for concrete cubes in Compressive Testing Machine of capacity 3000 kN.

b) *Split Tensile Strength Test:* Split tensile strength is well known indirect test used for determining the tensile strength of concrete. Direct measurement of tensile strength is very difficult so measure, hence indirect measurement through split tensile test is conducted.. This test is conducted on cylindrical specimen of diameter 100 mm and height 200 mm according to BIS 5816:1999.

c) *Flexural Strength Test:* Flexural tensile strength or modulus of rupture of concrete has been determined by applying the failure load on prismatic specimen at 3 and 7 days of curing with the beam of size 100 mm× 100 mm × 500 mm, using the flexural testing machine of 100 kN capacity. The beam specimen is kept under four point loading under rate of 0.5 mm/min. Flexural strength test was carried in the flexural testing machine. The testing machine is capable of evaluating flexural strength based on BIS 516. The beam specimen were kept on the roller support so that the loading arrangements of the prism be a four point loading.

IV. RESULTS

A. *Compressive Strength Results*

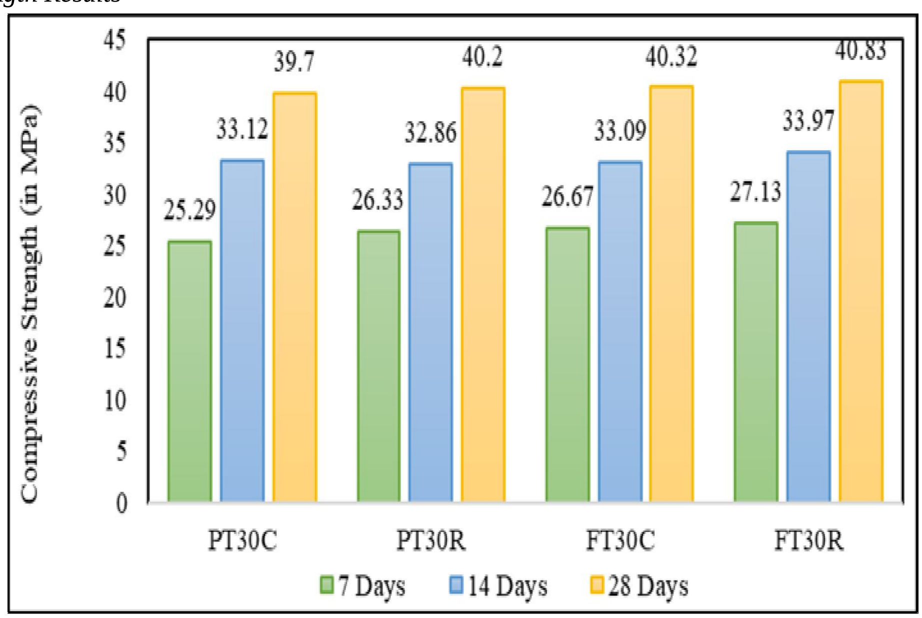

Fig 1. Compressive Strength for M30

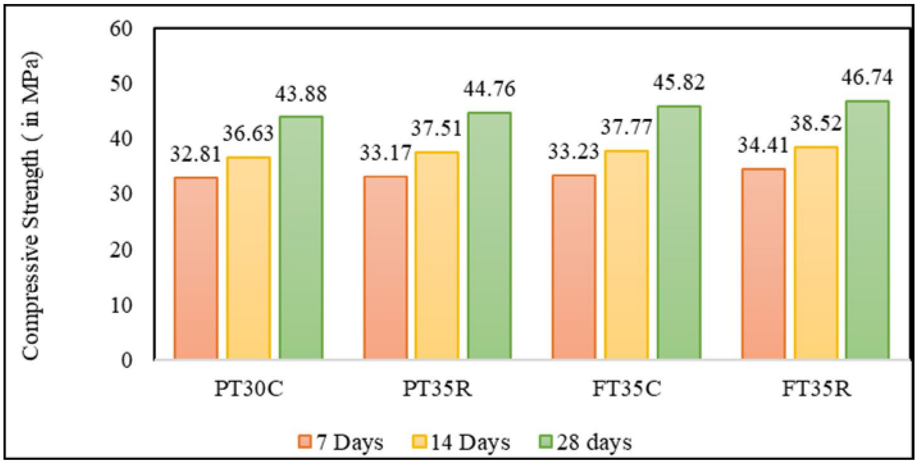

Figure 2. Compressive Strength for M35

B. Split Tensile Strength Results

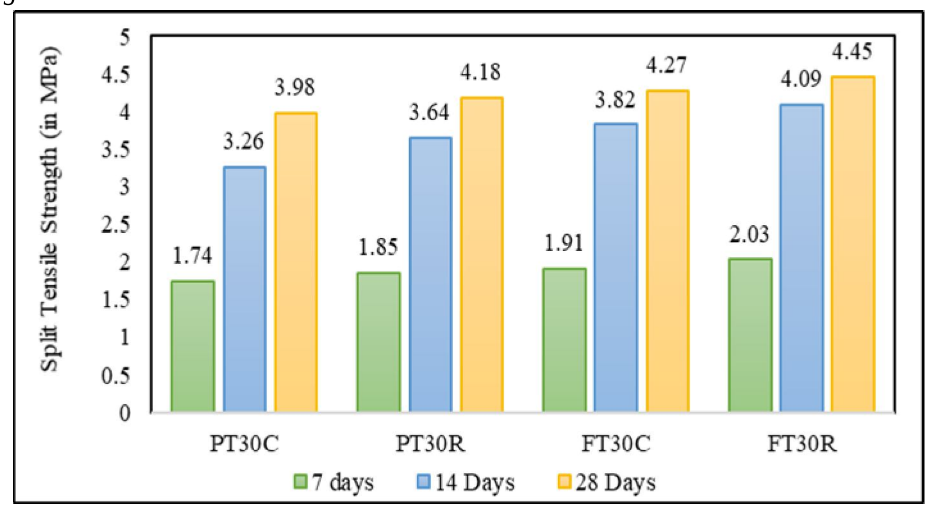

Fig 3. Split Tensile Strength for M30

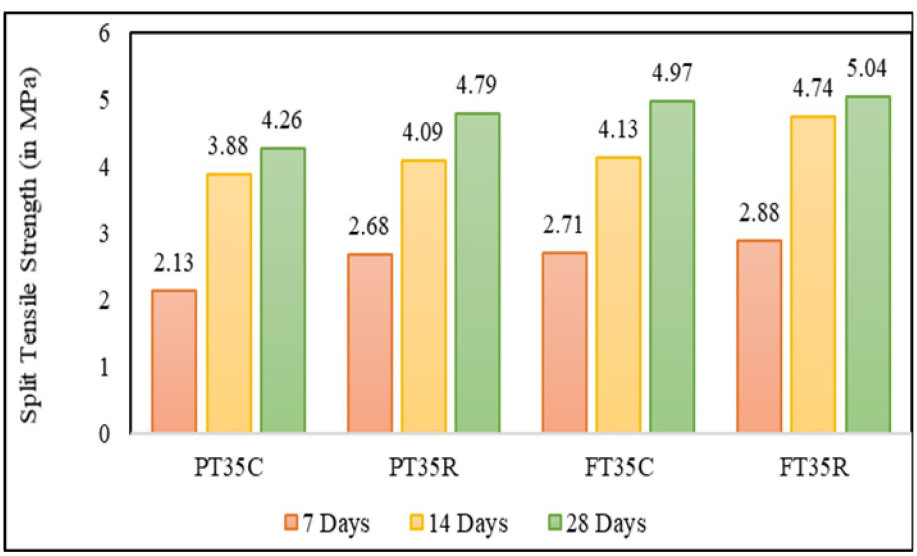

Fig 4. Split Tensile Strength for M35

C. Flexural Strength Results

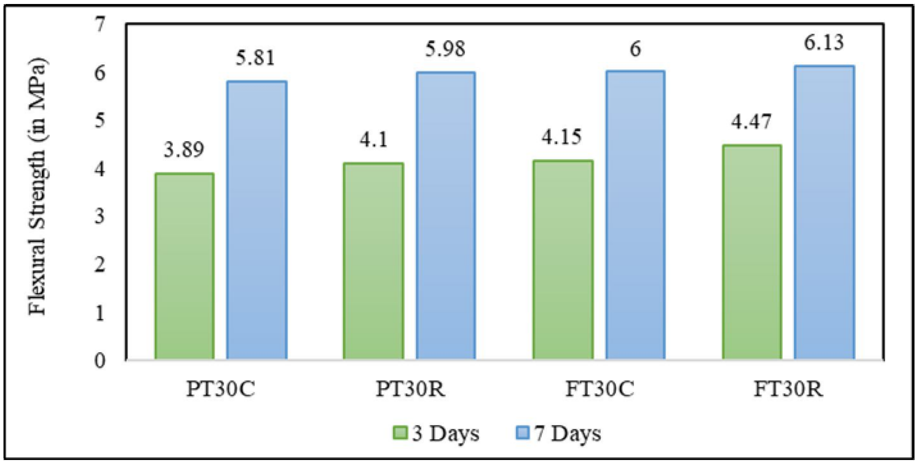

Fig 5. Flexural Strength for M30

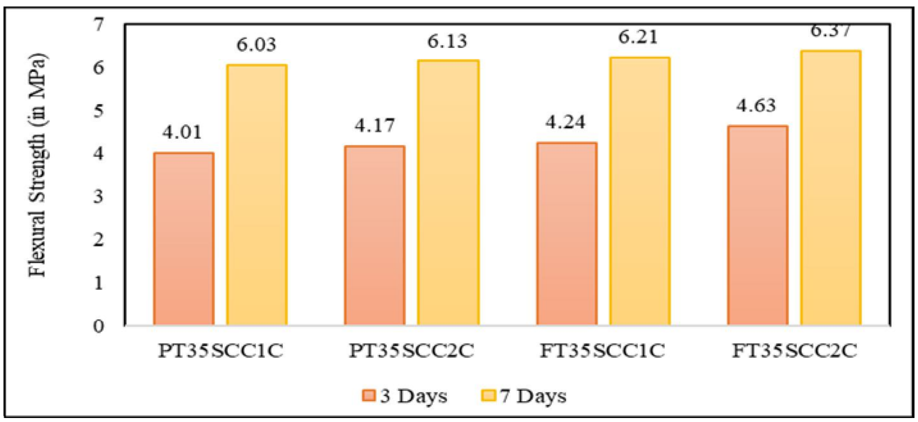

Figure 6. Flexural Strength for M35

V. CONCLUSION

Following were the conclusions drawn from result of M30 and M35 :

1) It can be inferred that when potable water replaced with treated wastewater partially, there was an increase of 33.3% and 24.07% in initial and final setting time for case 1 compared to case 2 are well within the codal provisions.
2) It was observed that when potable water replaced with treated wastewater fully, there was an increase of 17.39% and 20.41% in initial and final setting time for case 1 compared to case 2 are well within the codal provision.
3) From the workability test results of Slump flow on fresh SCC, it was observed that all the design mixes fall under the category of SF2 (660 mm - 750 mm). Under SF2 category, concrete is used for normal application as described in codal provision.
4) From the workability test results of V-Funnel on fresh SCC, it was observed that all the design mixes fall under the category of V2 (8 sec – 25 sec). Under V2 category, concrete helps in limiting foam work pressure and limiting segregation of concrete as described in codal provision.
5) From the workability test results of L-box on fresh SCC, it was observed that the passing ability ratio of all the design mixes were between the range of 0.8-1.0 as mentioned in the code.
6) From the compressive strength results at 28 days, it can be inferred that fully treated wastewater can be used as substitute for potable water as compressive strength for all the design mixes easily surpassed the target mean strength by 1.04 times.
7) From the split tensile and flexural strength test, it can be inferred that fully treated wastewater can be used as substitute for potable water as split tensile and flexural strength for all the design mixes has minimum tension bearing ability as per codal provisions.

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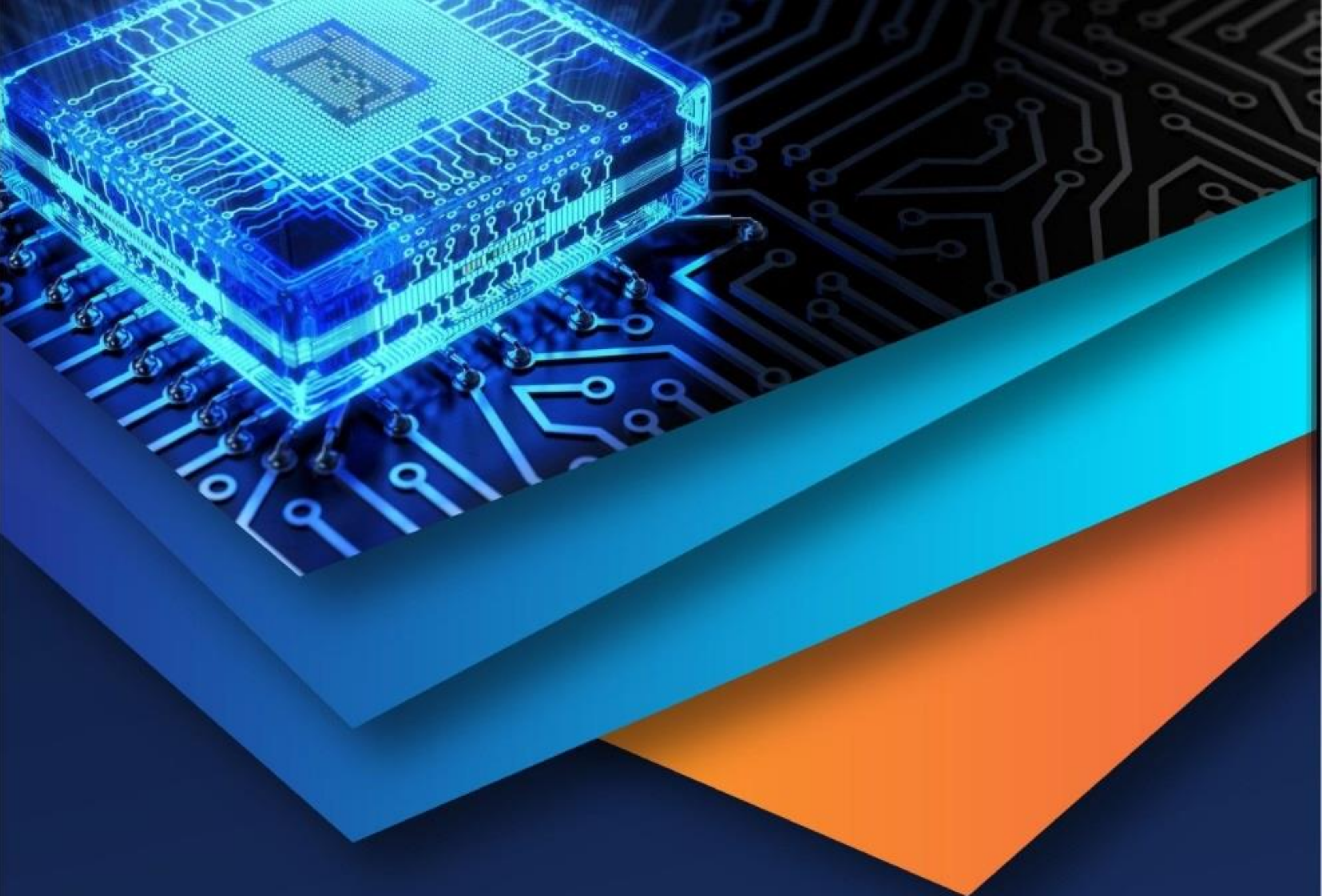

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