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Study to Find Out Shape Effect of Coarse Aggregate on Workability and Compressive Strength of Concrete

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Abstract: In this study, the shape of coarse aggregate particles has been related to the workability and compressive strength of cement concrete for rigid pavements. The shape characteristics such as elongation, flatness, shape factor, and sphericity were determined. Also,the slump and compressive strength of cement concrete were determined for various shapes of coarse aggregate. The test results indicated that there is a good correlation between some shape properties of aggregate, workability, and compressive strength.The highest compressive strength at different ages noted with concrete made from different shapes of coarse aggregates. Results indicate that the strength of concrete varies as a function of the shape of the coarse aggregate, which leads to the conclusion that the shape of aggregate shall be considered as an important parameter in deciding the suitability of coarse aggregate to prepare cement concrete for rigid pavements.

Key terms: Cement concrete, Coarse aggregate, Compressive strength, Rigid pavements, Shape, Workability

I. INTRODUCTION

To provide a stable and even surface for the traffic, the roadway is always provided with a suitably designed and constructed pavement structure. Thus, a pavement consisting of a few layers of pavement materials is constructed over a prepared layer of sub-grade to serve as a carriageway. Based on design consideration pavements can be classified as-Rigid pavements and Flexible pavement. Flexible pavements can be defined as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade. Rigid pavements are those, which possess note-worthy flexural strength or flexural rigid. The rigid pavement has the slab action and is capable of transmitting the wheel load stresses through a wider area below.

Cement concrete is a composite material produced by the homogenous mixing of selected proportions of water, cement, and aggregates (fine and coarse). Strength is the most desired quality of a good concrete. It should be strong enough, at hardened state, to resist the various stresses to which it would be subjected. Aggregates are the most important constituents in cement concrete. For a long time aggregates were considered as inert materials, but after 1940 it was brought out that aggregates do show some reactivity. The mere fact that aggregates constitute 70-80% of the volume of concrete, their impact on various characteristics is undoubtedly considerable.

Aggregates give the body to the concrete, reduce shrinkage, and affect the economy. Among all the characteristics of aggregates, the shape is most important because it affects the workability and compressive strength of cement concrete. Aggregates form the major portions of pavement structure and aggregates have to bear stresses occurring due to wheel loads on the pavement and on the surface-course they have to resist wear due to the abrasive action of traffic.

Therefore, the properties of aggregates are of considerable significance to the highway engineers. Significant findings indicate that aggregate plays a more "active" role than was previously believed, and a better understanding will result from further research. Several authors have indicated the need for more research to determine the effect of aggregate particle shape on the properties of concrete at present there is only alimited amount of information concerning the effect of aggregate particle shape on concrete proportioning, workability, and strength. This lack of information is reflected in specifications that place conservative limits on allowable amounts of particles of certain shapes. The present study was undertaken to investigate the effect of different types of coarse aggregate effect on the fresh and hardened Portland cement concrete behavior by a means of aggregate shape indexes such as elongation, flatness, roundness, shape factor, and sphericity.

II. REVIEW OF PREVIOUS WORK

Some of the previous works in this field are listed below:

Kaplan. M. F in (1959) [1]statistical analysis indicated that the shape, surface texture, and modulus of elasticity of the aggregates were the main cause of variation in concrete strength. From his research, he also published thatthe greater the strength, the greater these factors became and the elastic modulus of the aggregate was, in general, the most important single factor affecting flexural strength, although, for concrete with greater strength, the surface texture had the predominating effect. The surface texture was the most important aggregate property influencing concrete compressive strength.

Shilstone (1990) [2] presented that aggregate shape has a major influence on concrete. In his study, it is shown that mixes containing spherical and equidimensional particle sizes havebetter pumpability and finishability, and produce higher strengths and lower shrinkage than mixes containing flat and elongated particles. He explains that slum may be controlled by gradation changes without adjusting the water-cement ratio.

Ezeldin and Aitcin(1991) [3] explained the effects of coarse aggregate type and size on the compressive strength of normal and high-strength concrete concluded that normal-strength concretes are not greatly affected by the type or size of coarse aggregates. However, for high strength concretes, coarse aggregate type and size affect the strength and failure mode of concrete in compression.They found that cracks pass through the weaker portions of aggregate particles and then propagate into the cement paste. They also observed that the coarse aggregate types and sizes used in the study did not significantly affect the flexural strength of high-strength concrete. Vincent C Janoo (1998) [4] recommended from the research that aggregate shape, surface texture, angularity, and roughness even used in base-coarse have a significant effect on base performance.in this literature, it is clear that moisture and amount of fines have a significant effect on base course performance. Increasing moisture content, as during the spring thaw, can increase the failure rate of the base course.

Mansur and Islam (2002) [5] reported an experimental study on the effects of different concrete specimen types on the compressive strength and established the inter-relationships between their strengths. Each of a total of eleven test data sets generated in this study consists of five strength values for the five different types of test specimens. Each strength value was calculated by averaging the strength of at leastthree identical specimens. In this experimental study, two different high-strength concrete mixtures were used. The expected cube compressive strength of concrete mixes is M15 and M20.

Pedro.Nel.Quiroga et. al (2003) [6]based on the results from their study, it was found that the grading of aggregates affects significantly the performance of fresh mortar and concrete.The shape and texture of aggregates, cement, and supplementary cementing materials affect the packing density and consequently, they play an important role in the performance of fresh mortar and concrete.

Jian Shiuh Chen et al(2005) [7] in their study four types of aggregate shapes were used Cubical particles possessed the best rutting resistance over the other shapes. Flaky and elongated aggregate in a mixture resulted in lower resistance to shear deformation of the four-particle shapes evaluated. Flaky and elongated aggregate was shown to have lower compatibility and higher breakage.

D. Sakthibalan (2009)[8] the shape of the aggregate particle has a significant influence on the performance of the bituminous concrete pavement. The presence of flaky aggregates is considered undesirable in bituminous concrete mixtures because they tend to break down during construction and subsequent traffic operations. The voids present in a compacted mix depend on the shape of aggregates. Highly flaky aggregates have more voids and reduce the workability.

M R Vyawahare and P.O.Modani (2009) [9] from their investigation, it can be concluded that extremely flaky and elongated aggregate can also produce quality concrete that can be used for PCC works like Pavements, Factory floors, Foundations. With the W/C ratio of 0.4, a dose of super-plasticizer 0.80 and optimum powder content (Fly ash) 0.25 the concrete with any proportion of flaky and elongated aggregate replacing normal aggregate can produce workable concrete with acceptable strength. The 20% replacement of normal aggregate with flaky and elongated aggregate has proved to be equally good as concrete made up with normal aggregate. K. Jain, Dr. J. S Chouhan(2011) [10] discussed from their study that shape characteristics of coarse aggregate must be taken into consideration to manufacturing pervious concrete to optimize its compressive strength and permeability. The aggregate of minimum possible angularity number and size, practically and economically available, shall be used to manufacture pervious concrete. An aggregate of desired angularity numbers may be manufactured to prepare pervious concrete.

Mehrzad Mohabbi Yadollahi et al (2013) [11] found a strong correlation between some shape indexes of aggregate and compressive strength of concrete. The particle shape factors were shown to be an adequate measure of the combined contribution of some particle shape factors such as flatness, elongation, and sphericity to the compressive strength of aggregate. Spherical particles were desirable for increased compressive strength, unit weight, and slump values of concrete. The more nearly spherical the aggregate, the higher the mentioned values.

M Markandeya Raju Ponnada (2014) [12] in his study M_{25} grade concrete was used for different ratios of weights of elongated, angular, and flanky aggregates and were tested for compressive strength, density, and workability. The results reveal that the effect of elongated aggregate is more than flanky aggregate on the characteristic compressive strength of concrete. For a constant EA (elongated aggregate): FA (flanky aggregate) ratio, density increases but characteristic compressive strength and compaction factor decrease.

Himanshu Kumar et al (2015) [13] this study was performed to evaluate the effect of the flaky and normal aggregates having different mix conditions on the compressive strength of cement concrete. Compressive strength was obtained higher for normal aggregate than flaky. Also, it was obvious that Compressive strength increases with the decrease in the size of the flakiness index for M_{15} and M_{20} grade of concrete. Also, the mixtures with rough aggregates have higher strength, especially tensile strength, at early ages than a corresponding concrete with smooth or naturally weathered aggregate.

Ashok Kumar Tripathi and Yogendra Singh (2016) [14] from their study, the results of the slump, it is observed that slump value increases when flaky aggregates are up-to 10% with 10 mm approximate size and reduces beyond that. The same pattern is observed in M_{20} and M_{25} concrete. In the case of the compressive strength test, it is observed that there is a drop in the compressive strength of M_{20} concrete as the amount of flaky aggregate and aggregate size is increased. However, in M_{25} concrete there is a significant rise after a drop in compressive strength.

B.V.R.Murthy et.al (2018) [15] investigated the effect of flaky aggregate on the workability and strength properties of concrete. The main aim of this study was to find the optimum percentage of flaky aggregate allowable in the concrete to obtain better workability and strength. From the experimental work, it is concluded that 20% of flaky aggregate is acceptable in the total coarse aggregate for getting better strength and workability. Hence the optimum percentage of flaky aggregate in the concrete is 20%. By the addition of admixture, the concrete with 20% of flaky aggregate also shows good improvement in compressive strength and workability.

III. MATERIALS AND METHODOLOGY

The locally available river sand was used as fine aggregate in the present investigation. Sieve analysis for the sand was carried out in the laboratory as per the procedure mentioned in IS 2386 (part-i)-1963. The sizes of sand vary between 2 mm to 4.75 microns. The purpose of fine aggregates is to fill the voids in the coarse aggregate and to act as a workability agent. Carefully handpicking of the coarse aggregate of different shapes was the major problem in this study. Coarse aggregate was handpicked from the riverbed of Sindh River, Ganderbal (Jammu and Kashmir). Grading of natural coarse aggregate considered as per IS: 456:2000. Six types of coarse aggregate were used. Based on their shape characteristics, the aggregates were classified as elongated, elliptical, oval, blade, flaky, and angular as per the classification given in IS: 2386 (part ii)-1963.The test samples collected were sieved to separate them into single size fractions. Tests like flakiness index, elongation index, sphericity,and shape factor were conducted. Ordinary Portland cement (53-grade) confirming Indian standard (is 12269:1987) was used in the present study.The batching of the concrete was done and a nominal mix M_{20} with the general mix proportion ratio of 1:1.5:3 was adopted. The concrete mix design is done following IS: 10262 (1982). A water/cement ratio of 0.6 was employed.After wet concrete is poured, the concrete dries to what is known as the "workable" state of the concrete. After these tests like the slump test and compaction-factor test were performed to determine the workability of fresh concrete. The casting of the cube was done in a single stage. 36 cubes were cast in total, containing six cubes of each shape. All cubes were cast for M20 grade of concrete mix. The cubes were cast in the mould of size 150 x 150 x 150 mm. Cubes were represented as sample-1, sample-2, sample-3, sample-4, sample-5, and sample-6 (Total-36 samples) from each shape taken for easy identification.The moulds were removed after 24hoursand curing starts.At the age of 7-days (18 cubes, 3 from each shape), 28-days(18 cubes, 3 cubes from each shape) were tested under a compression testing machine.Then the ratio of crushing load to the area of the specimen is taken as the compressive strength of the specimen and was averaged for each type of aggregate shape. It should be noted that if the average strength of any specimen varies more than 15% of average strength, the result of such specimen should not be taken into consideration.

Fig.1.1: Various shapes of coarse aggregate

IV. RESULT AND DISCUSSION

1) *Aggregate Properties:* The mean value for each shape properties of aggregates is listed in Table 1.1. The results showed that there exist distinct morphological characteristics for different aggregate shapes (i.e. spherical, elliptical, blade, flaky, elongated, and angular).

Table 1.1: The average values of aggregate shape properties

S. N	PROPERTIES	SHAPES					
		SPHERICAL	ELIPTICAL	BLADE	FLAKY	ELONGATED	ANGULAR
1	Sphericity	0.90	0.78	0.71	0.55	0.47	0.53
2	Shape Factor	0.82	0.67	0.50	0.24	0.40	0.46
3	Flakiness Index	1.32	1.55	2.02	4.36	3.04	2.42
4	Elongation Index	0.9	0.72	0.79	0.71	0.37	0.53

2) *Workability:* The results of the slump test and compaction-factor test to determine the workability is shown in fig. 1.2 and fig. 1.3. From fig. 1.2, it can be seen that the spherical aggregate mixture is the best mixture and elongated aggregate mixture is the weakest mixture followed by flanky aggregate. It also shows that the slump of concretes produced with spherical aggregates is higher than the slump of concretes produced with flat, elongated, and mixed type aggregates. Under, the spherical aggregate surface area is less and because of less friction of spherical aggregates in concrete, workability is good than concretes produced with other aggregate types. Fresh concrete unit weight depends on voids in concrete, workability, aggregate grading, and aggregate type. As a result of Fig. 1.3, the concrete that has been made with elongated aggregate had the minimum unit weight equivalent with 2.38 and after that, the increase in unit weight has been observed orderly from flaky aggregate, blade, elliptical, spherical, and angular aggregates that are 2.39, 2.40, 2.41, 2.42 and 2.40 orderly.The effect of shape and surface texture of aggregates on mechanical properties is often not a factor in conventional concretes (20-30 Mpa), although these properties may cause an increase in the water demand. For these concretes, the hydrated cement paste and the transition zone around the aggregate are relatively weak.

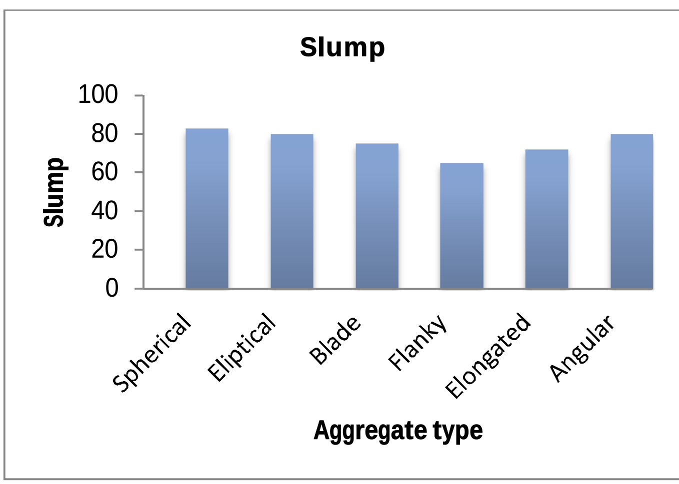

Fig:1.2. The Correlation between Slump and fresh coarse aggregates shape

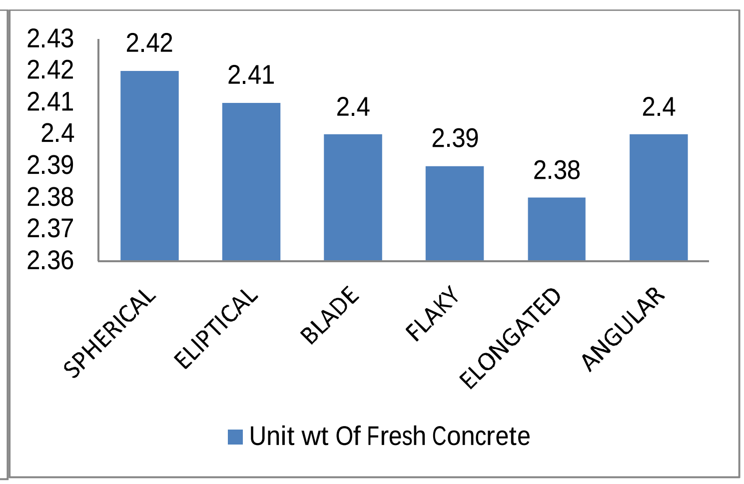

Fig:1.3.The correlation between the unit weight of concrete and shape of coarse aggregate

3) *Compressive Strength:* The results were plotted in a graph as shown in fig.1.4 and fig.1.5, from the plotted graphs it is clear that none of the shapes have an individual effect on compressive strength.

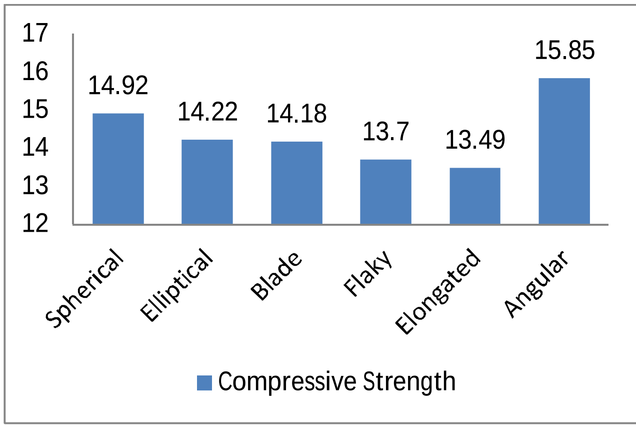

Fig.1.4: Correlation between compressive strength and The shape of aggregate after 7 days

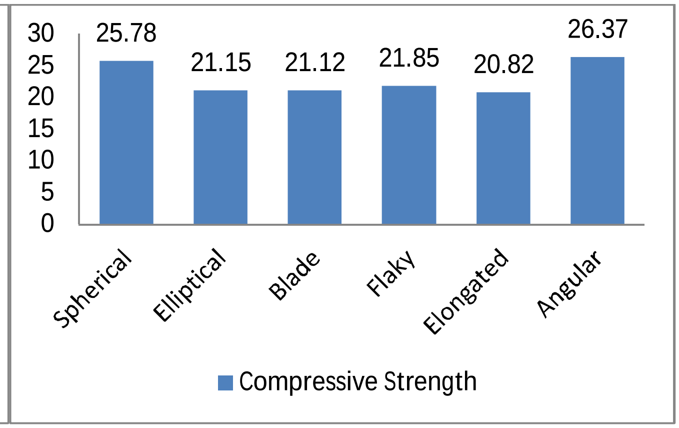

Fig.1.5: Correlation between compressive strength and shape of aggregate after 28 days

In fig.1.6, there is a positive correlation (R^2=0.1047) between sphericity and Compressive strength. In the figure, It can be seen in Fig. 1.7, there exists a positive (R^2=0.141) correlation between the shape factor and compressive strength.

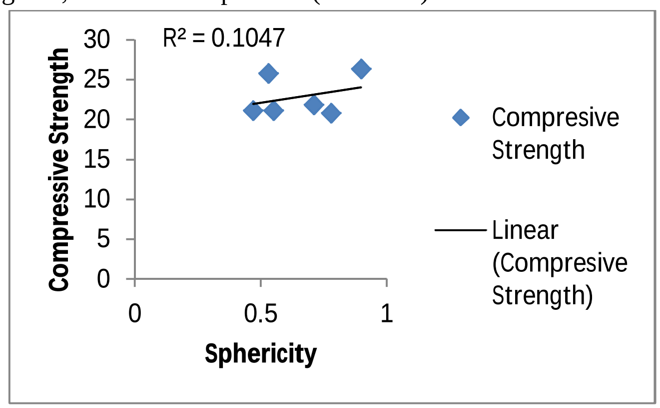

Fig:1.6The correlation between sphericity and compressive Strength

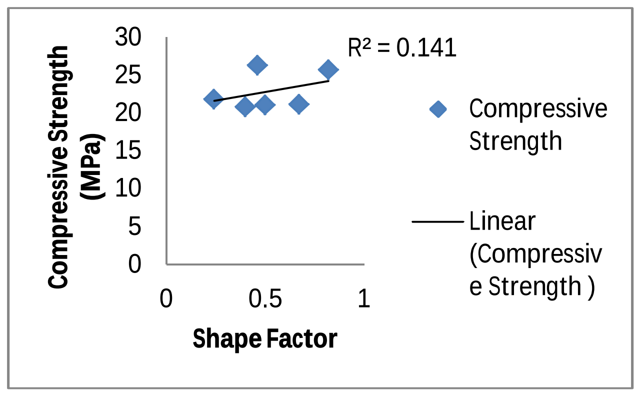

Fig:1.7 The correlation between shape factor and Compressive strength

Also from fig.1.8, there is a positive correlation (R^2= 0.189) between the flakiness index and compressive strength. Fig.1.9, the best positive (R^2=0.208) correlation existed among the elongation index and compression strength.

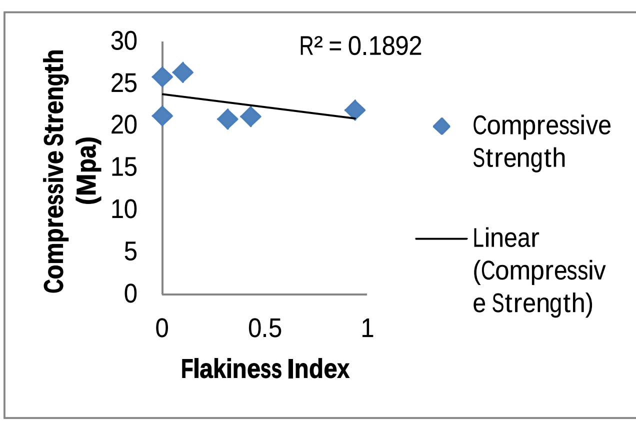

Fig:1.8 Correlation between flakiness index and Compressive strength

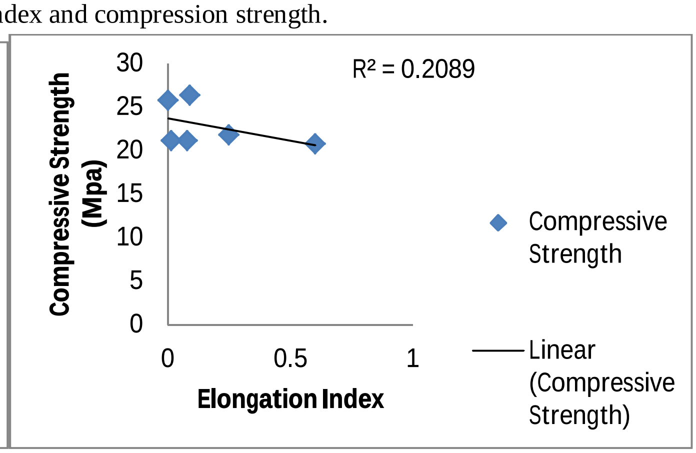

Fig:1.9 Correlation between elongation index and Compressive strength

V. CONCLUSION

Based on the results of this investigation which have been discussed above, the following conclusions can be drawn:

1) The results of this study indicate that coarse aggregate shape does influence concrete strength in rigid pavements. Concrete made with elongated coarse aggregate (length three times width) had the lowest strength.
2) The particle shape factors were shown to be an adequate measure of the combined contribution of some particle shape factor such as flakiness, elongation, and sphericity to the compressive strength of aggregate.
3) Spherical aggregates should be preferred for cement concrete mix due to low specific surface area, better workability, increased compressive strength, increased unit weight, and better slump values for the same proportion of cement paste and same water-cement ratio.
4) Spherical aggregates should be avoided in the granular base course, WBM construction and bituminous construction as the stability due to the interlocking of these particles is less. Angular particles are preferred for such constructions.

VI. FUTURE SCOPE

Several authors have indicated the need for more research to determine the effect of aggregate particle shape on the properties of concrete at present there is only alimited amount of information concerning the effect of aggregate particle shape onconcrete proportioning, workability, and strength. Test results of this study were compared with previous studies and, it was undertaken on the hypothesis that coarse aggregate particle shape has a definite effect on concrete strength. It is hoped that the results of this study will add to the general knowledge, and thereby aid in establishing a sound basis for the acceptance or rejection of aggregates for cement concrete in rigid pavements.The full influence of aggregate particle shape upon concrete strength in rigid pavements can only be determined by a series of tests.Tests should also be made to determine which aggregate proportions are best for each particle shape as this is extremely important.Further studies should be subjected by studying the aggregate shape properties with digital image processing to make more reasonable judgments.

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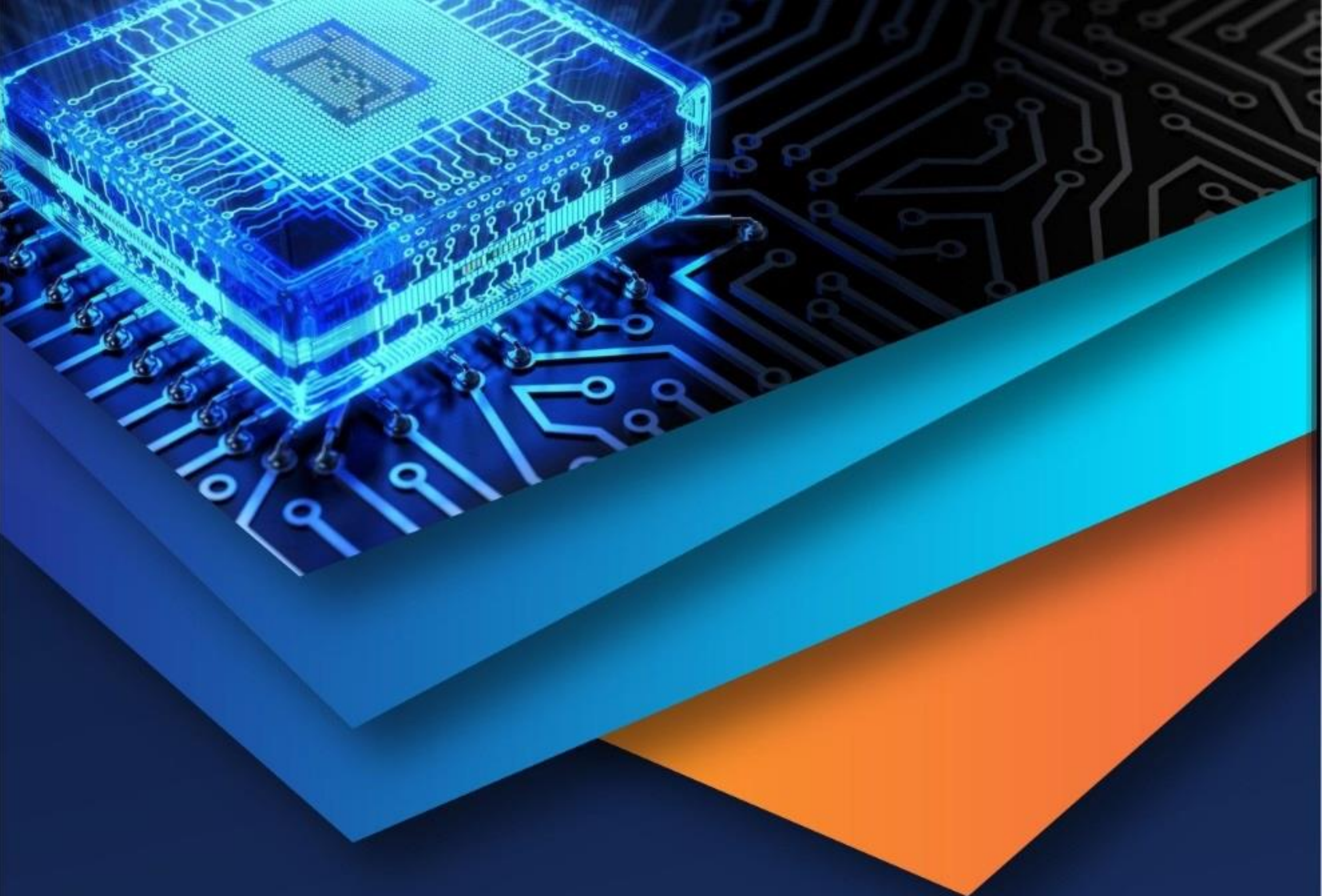

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