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Manufactured Sand with Rock Quarry / Muck Material – A case study

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Abstract: ***Manufactured sand is an alternate to natural sand in concrete industry. Availability of good natural sand is limited and localized. Issue discussed in this paper is, when availability of natural sand is almost negligible and good quality stone quarries are also limited for crushing, what will be the impact on the final strength of concrete if crushed sand manufactured with locally available materials and used for making concrete.***
Index Terms: Crushed sand, Gradation, Muck material and VSI.

I. INTRODUCTION

For the river valley projects, obtaining good quality natural sand is a real challenge. Due to environmental consequences, several restrictions were imposed by the Apex Court which results in rapid decline of natural river sand mining and it is a concern much to the concrete industry all over India. Pressure due to infrastructure development on construction industry is enormous; whereas availability of natural sand is limited. It is the requirement of time to use manufactured sand by the construction industry to reduce down the gap between demand and supply. It has proven fact that manufactured sand is equally good for construction but before use in concrete there is a need to study on micro fines, shape characteristics, concrete mix proportioning by resorting to particle packing approach [1], shrinkage, creep etc.

II. MATERIALS AND METHODS

A. Materials for Crushed Sand

Generally manufactured sand shall be produced by crushing and screening of sound and durable rock sources confirming to the requirement of coarse aggregate for the use in concrete. Aggregate properties depend on the properties of the parent rock (e.g., chemical and mineralogical composition, petrographic classification, texture, surface properties, alterations, specific gravity, hardness, strength, physical and chemical stability, pore structure and colour). All these properties have an important influence, both upon the blasting and crushing of manufactured sand, e.g. energy consumption, fines production and shape. Rock sources which have a tendency to produce flaky chips should be avoided for manufactured sand production. Crushing shall include processes to improve the particle shape of the manufactured sand. Production processes shall ensure that sand stockpiles are not contaminated with weathered or highly altered rock or with clay or any other contaminants.

B. Manufacturing Processes of Crushed Sand

Manufactured sand has been produced by a variety of crushing equipment like cone crushers, impact crushers; roll crushers, rod mills etc. Control of particle shape and control of gradation (dust and intermediate fines) are two most important operations in the processes of manufactured sand. Unless otherwise it is controlled, difficult to obtain strength and workability comparable to those obtained with natural sand. A normal crusher set-up will have a primary crusher (usually a jaw or a large gyratory), one or two secondary crushers which will in most cases be cone crushers, in large quarries even a tertiary cone stage may be used. And then as a final (third or fourth) stage for making cubical fine grained particles, a Vertical Shaft Impactor (VSI) has often been the solution [2]. It is fact that gyratory or cone crushers producing crushed sand of the flabby particle shapes. On the other hand, impact crushers such as hammer mills and rod mills yield excellent cubical shapes. VSI has proved to be an effective way of producing cubical (even rounded) particles in the small and medium size fractions (< approx 5 mm). It is a challenge to avoid generating of high percentage of fines. However, the advancement in this field with latest generation of dry screening equipment combined with the latest development of air classification have, enabled to govern the grading curve very precisely, including the finest part. Configurations of machinery from e.g. Metso/Buell or the V7 concept from Kemco in Japan are good examples, where manufactured sand has been produced for 100% use in concrete. [3]

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III. TEST METHODS FOR MANUFACTURED SAND

A. Grading and Passing 75-Micron

Particle size analysis (grading) conducted as per IS:383-2016 on manufactured sands (down to the 75-micron size fraction) is useful for determining the total combined particle distribution, an indicator of particle packing or voids within a concrete mix. From this perspective, grading is considered a reportable test, and would be specified in a supply agreement for any particular source. For assessing manufactured sand, the grading is a necessary test for design and quality control of concrete [3].

B. Sand Equivalent Test

The sand equivalent test (IS 2720 Part 37) provides a measure of the relative proportions of detrimental fine dust or clay-like material in soil or fine aggregates. A measured volume of soil or fine aggregate and a small quantity of flocculating solution are poured into a graduated plastic cylinder and are agitated to loosen the clay-like coatings from the sand particles in the test specimen. The specimen is then processed using additional flocculating solution forcing the clay-like material into suspension above the sand. After a prescribed sedimentation period, the height of flocculated clay is read and the height of sand in the cylinder is determined. The sand equivalent is the ratio of the height of sand to the height of clay times 100.The test is used to qualify aggregates for applications where sand is desirable but fines and dust are not. A higher sand equivalent value indicates that there is less clay-like material in a sample

C. Durability Tests

Durability tests to determine resistance to disintegration of fine aggregates by saturated sodium sulphate or magnesium sulphate solution can be done as per IS 2386 (Part V). This test furnishes information helpful in judging the soundness of aggregates subject to weathering action, particularly when adequate information is not available from service records of the material exposed to actual weathering conditions.

D. Mortar Trials

Potential manufactured sand sources and the possible blends of the manufactured sand with available natural sands are evaluated rapidly by using a structured series of mortar trials. These trials provide useful information on the probable effects of the manufactured sand on the properties of the concrete without the variables of aggregate performance, admixtures or supplementary cementitious materials having to be considered at the design stage. Once a suitable blend of the manufactured sand with natural sand has been determined, the selected blend can be confirmed in full-scale mix design tests [3].

IV. EXPEREMENTAL INVESTIGATION

Experimentation has been modeled to see the effect on compressive strength of concrete, mix design has been done with two types of manufactured sand i) crushed sand by crushing rock quarry material and ii) crushed sand by crushing quarry rock and muck material.

A. Materials

The materials used for mix are PPC, manufactured sand blended with 50-50% crushed and VSI sand from rock quarry designated as SR-1, SR-2 and SR-3 and hence forth read as Crushed Sand – I and in another set crushed sand from quarry rock and muck material designated as SRM-1, SRM-2 and SRM-3 and hence forth read as Crushed Sand – II, 20 mm and 10 mm size coarse aggregate from rock quarry and water reducing admixture. Keeping the grading of crushed sand in Zone-II.

Petrographically rock quarry materials were hard, compact, massive, metamorphic consisting sub-rounded to sub-angular quartz with quartzo-feldspathic gneiss. It consists mainly fine grained quartz and feldspar with minor amount of sericite, biotite, chlorite and iron oxides. Quartz is anhedral to subhedral, fine to medium grained. Some of the quartz grains are recrystallised.

The muck material (rock) is foliated and laminated, metamorphic and consisting mainly quartzo- feldspathic gneiss with bands of biotite gneiss / veins of crushed pegmatite.

It consists of mainly fine to medium grained quartz and feldspar with some amount of biotite, and muscovite. Biotites occur as fine flakes, along the boundary of quartzo-feldspathic grains.

The properties of the materials are shown in the following tables:

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Table -1: Four Cement Samples of Different Weeks had been tested for their Physical Properties and Test Results are shown as below:

Sl No	Type of Cement	Normal Consistency	Soundness (mm)	Setting Time (Min)		Fineness (90µ retained)	Compressive Strength (MPa)		
				Initial	Final		03 days	07 days	28 days
1	PPC 18.16	29.5	1.2	124	176	1.58	26.10	34.80	44.20
2	PPC 19.16	29.5	1.1	138	194	1.36	27.8	33.60	46.40
3	PPC 20.16	29.0	1.3	136	179	1.25	24.60	30.30	43.60
4	PPC 21.16	30.0	1.2	146	193	1.23	18.70	29.20	52.00

Table 2: Grading of Crushed Sand – I presented below.

Sample no → Sieve ↓	SR-1	SR-2	SR-3	Criteria Limits for Zone-II
10 mm	100	100	100	100
4.75 mm	100	97.65	98.40	90-100
2.36 mm	98.20	77.10	76.20	75-100
1.18 mm	74.20	53.62	52.60	56-100
600 µm	46.20	41.49	43.00	35-59
300 µm	35.40	30.92	36.00	8-30
150 µm	28.20	20.94	26.20	0-20
<75 µm	12.40	13.11	13.56	-
FM	2.97	2.78	2.68	-

From the above table it can be seen that the FM limit varies from 2.68 to 2.97. The corresponding graph for the gradation of SR-1, SR-2 and SR-3 are presented in fig 1.0, fig 2.0 and fig 3.0. Upper and lower limits of the graph represents the boundary limits of Grading Zone-II as per IS 383-2016.

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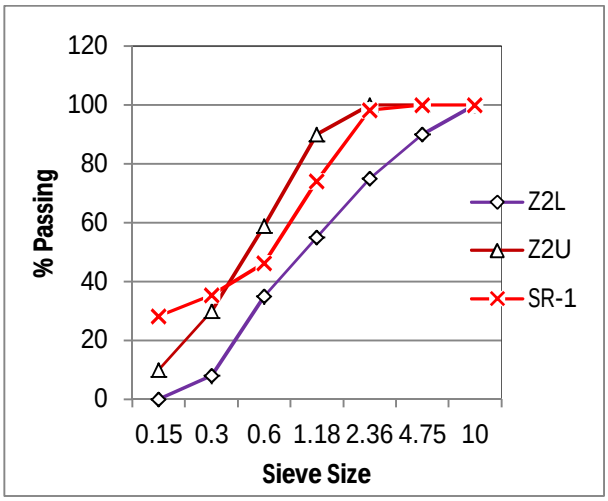

Fig 1.0

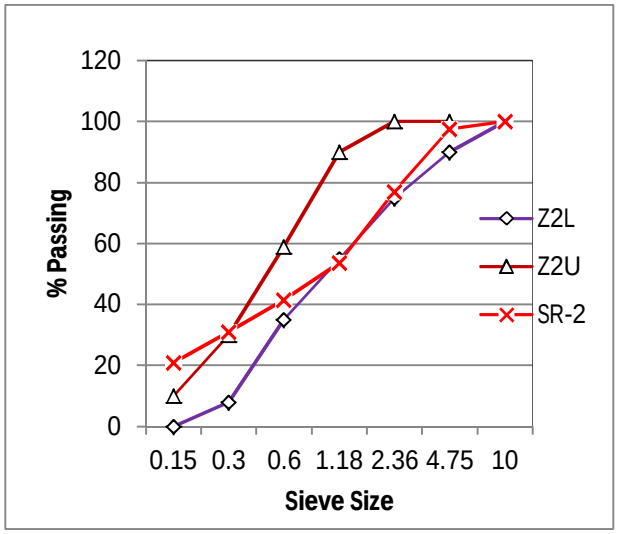

Fig 2.0

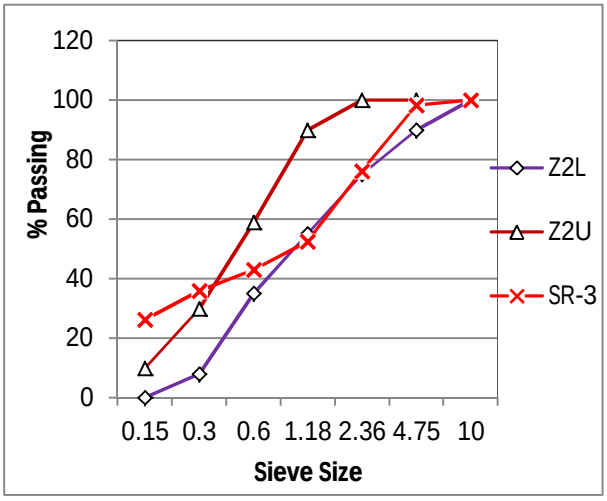

Fig 3.0

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From the above gradation curves it has been observed that in Crushed Sand-I finer fraction (< 150 µm) are more than the permissible limit.

Table 3: Grading of Crushed Sand -II presented below.

Sample no → Sieve ↓	SRM-1	SRM-2	SRM-3	Criteria Limits for Zone-II
10 mm	100	100	100	100
4.75 mm	98.20	98.61	97.70	90-100
2.36 mm	77.73	79.48	80.30	75-100
1.18 mm	50.97	53.22	62.20	56-100
600 µm	39.38	41.83	42.90	35-59
300 µm	29.99	28.17	25.2	8-30
150 µm	20.72	18.96	10.70	0-20
<75 µm	7.70	10.43	10.04	-
FM	2.83	2.80	2.81	-

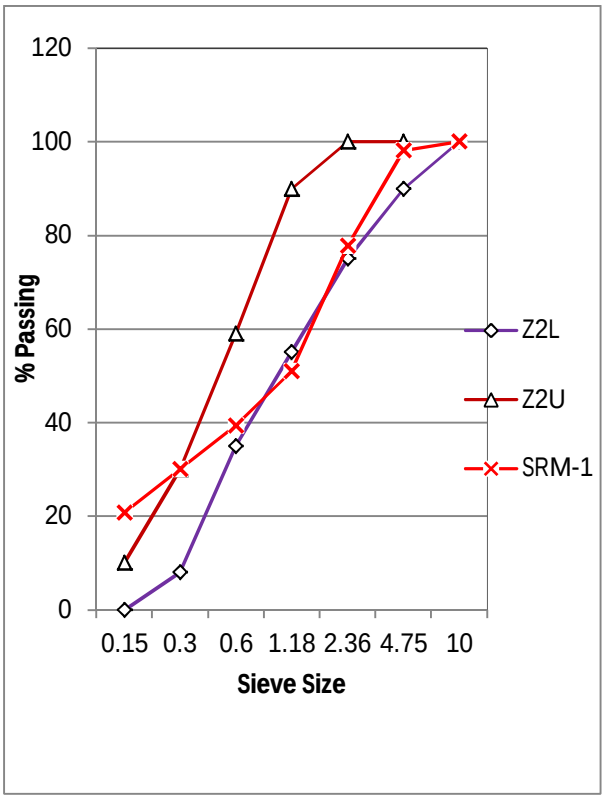

Fig 4.0

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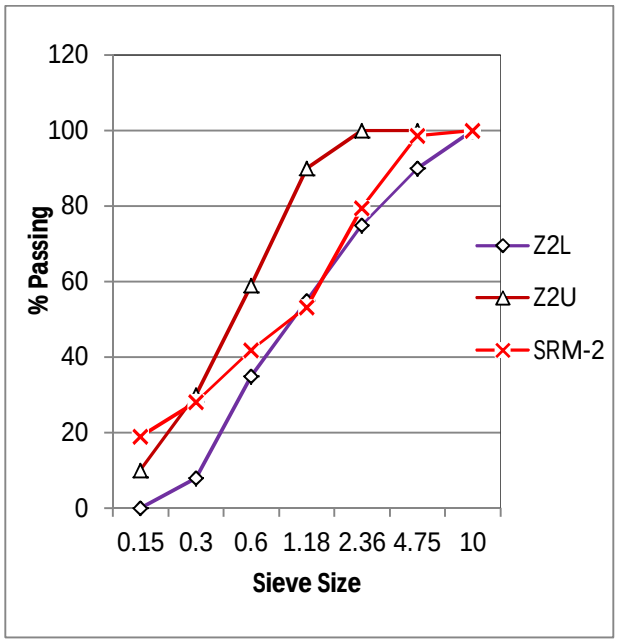

Fig 5.0

From the Table-3, it can be see that the FM limit varies from 2.80 to 2.83. The corresponding graph for the gradation of Crushed Sand - II is presented in fig 4.0, fig 5.0 and fig 6.0. Upper and lower limits of the graph represents boundary limits of Grading Zone-II as per IS 383-2016.

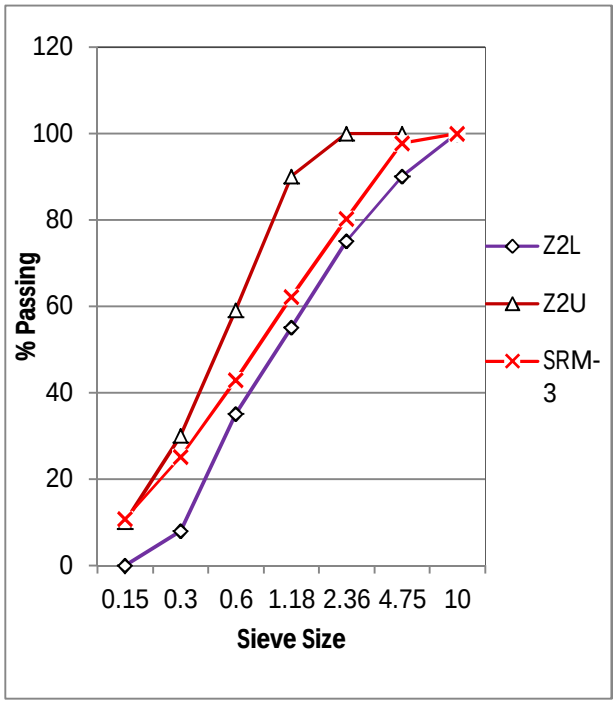

Fig 6.0

From the above gradation curves it has been observed that finer fraction (< 150 µm) much less then Crushed Sand - I However, finer fraction (< 150 µm) is more than the permissible limit as per IS 383-2016.

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Table 4: The Physical Properties of the Rock Quarry Materials i.e. Specific Gravity, Water Absorption, Flakiness Index, Elongation Index, Soundness Loss, Impact Value, Abrasion Value and Crushing Value are shown below:

Sl No	Sample No	Sp Gr	Water Absorption	Flakiness Index	Elongation Index	Soundness Loss	Impact Value	Abrasion Value	Crushing Value
1	C-1	2.68	0.76	12.68	13.17	1.20	22.19	27.20	18.96
2	C-2	2.70	0.57	12.52	13.81	0.85	20.36	27.80	19.36
3	C-3	2.72	0.39	12.11	13.14	1.90	21.84	32.68	20.05
4	C-4	2.68	0.70	11.57	12.71	1.20	19.25	28.54	18.22
5	C-5	2.71	0.52	11.14	13.16	1.00	14.72	20.78	19.65
6	C-6	2.67	0.71	13.30	14.15	1.10	19.90	28.20	25.82
7	C-7	2.70	0.52	11.26	13.14	0.70	14.29	23.36	19.65
8	C-8	2.69	0.54	11.07	14.29	1.05	19.10	30.72	19.37
9	C-9	2.71	0.57	12.12	13.02	1.45	17.10	29.14	18.65
10	C-10	2.70	0.38	13.96	14.92	1.40	20.67	29.64	19.42

Table 5: The Physical Properties of the Muck Materials i.e. Specific Gravity, Water Absorption, Flakiness Index, Elongation Index, Soundness Loss, Impact Value, Abrasion Value and Crushing Value are shown below:

Sl No	Sample No	Sp Gr	Water Absorption	Flakiness Index	Elongation Index	Soundness Loss	Impact Value	Abrasion Value	Crushing Value
1	C-11	2.56	0.75	4.57	5.62	1.60	39.32	50.42	31.87
2	C-12	2.59	1.08	3.32	4.51	1.15	39.12	51.00	32.87
3	C-13	2.59	1.06	3.66	4.71	1.00	40.49	49.42	32.60
4	C-14	2.60	1.10	3.10	4.39	1.15	40.15	51.55	35.22
5	C-15	2.57	1.02	3.58	4.83	1.40	40.02	48.87	33.65
6	C-16	2.61	0.85	4.10	4.96	1.00	38.86	48.61	31.82
7	C-17	2.57	1.00	4.65	5.59	1.60	39.68	50.40	31.65
8	C-18	2.59	1.14	3.84	4.75	1.75	39.16	49.04	31.37
9	C-19	2.61	0.92	3.96	5.10	1.25	39.10	50.26	30.65
10	C-20	2.60	1.08	4.12	5.36	1.25	40.45	51.12	31.42

Table 6: Compressive Strength of Concrete of Different Grades using Fine Aggregate as Crushed Sand-I and Quarry Stone as Coarse Aggregate in concrete as shown below:

Sl No	FM	% Finer than 75µm	Slump			28 days comp strength		
			M15A20	M25A20	M30A20	M15A20	M25A20	M30A20
1	2.97	12.40	155	150	145	22.13	31.21	36.67
2	2.97	12.40	150	160	140	22.34	30.40	36.58
3	2.97	12.40	160	150	160	22.55	29.88	36.90

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4	2.78	13.11	150	155	145	22.37	30.03	36.87
5	2.78	13.11	155	160	160	22.07	30.34	36.72
6	2.78	13.11	150	160	160	22.86	30.33	36.84
7	2.68	13.56	150	150	150	22.59	30.47	36.95
8	2.68	13.56	155	160	160	22.73	30.41	36.13
9	2.68	13.56	155	150	160	22.74	30.47	36.21

Table 7: Compressive Strength of Concrete of Different Grades using Fine Aggregate as Crushed Sand-II and Quarry Stone as Coarse Aggregate in concrete as shown below

Sl No	FM	% Finer than 75µm	Slump			28 days comp strength		
			M15A20	M25A20	M30A20	M15A20	M25A20	M30A20
1	2.81	7.70	135	140	145	22.68	31.24	36.84
2	2.81	7.70	140	140	140	22.58	31.42	36.87
3	2.81	7.70	140	150	150	22.76	31.0	36.74
4	2.80	10.43	140	150	150	22.50	36.76	36.90
5	2.80	10.43	140	155	140	22.69	30.95	37.04
6	2.80	10.43	145	145	150	22.80	31.32	37.23
7	2.83	10.04	140	140	145	22.93	31.29	37.11
8	2.83	10.04	140	155	145	22.73	31.56	37.32
9	2.83	10.04	140	140	150	22.68	31.17	36.58

V. OBSERVATIONS AND CONCLUSION

It has been observed that physical parameters of samples of rock quarry are confirming to wearing surfaces except C-3 and C-8 samples, whereas physical parameters of muck materials are confirming to non-wearing surfaces. Soundness loss of both the samples are comparable and well within the criteria limit as per IS 383-2016. Very good cohesive and consistent mix was obtained with Crushed Sand – II rather than Crushed Sand – I. This happens due to particle shape of the manufactured sand. . Shape of the particles of Crushed Sand-II was cuboidal whereas Crushed Sand-I was having flaky in nature, cause of which to make consistent mix was difficult / not possible. Significant slump loss has been observed while comparing two mixes of the same grade keeping all the variables same. It has also been observed from the sieve analysis that percentage finer than 75 µm fractions is more in the Crushed Sand-I in comparison to Crushed Sand-II.

Durability of the concrete depends mostly on permeability, compactability, strength and material quality. In a unit composition of concrete 70-80 % volume occupied by aggregate and out of which 30 -35 % volume occupied by the fine aggregate [4]. Based on the test results, it is concluded that crushed sand manufactured with quarry and muck materials can be used to produce concrete provided the aggregates (both coarse and fine) from rock quarry, tunnel muck and blended sand meet the physical, chemical and durability criteria especially soundness losses as per IS 383-2016.

VI. FUTURE RESEARCH SCOPE

It is evident that though both the crushed sand used in the mixes are comparable in respect of compressive strength of concrete with same cement, aggregate, water cement ratio, admixture type and its doses. Durability study of concrete is required to be checked in longer run for re-use of tunnel muck having high abrasion loss but meeting the requirements for use in non-wearing surfaces as per IS 383-2016 as a granular material in the form of crushed sand in concrete.

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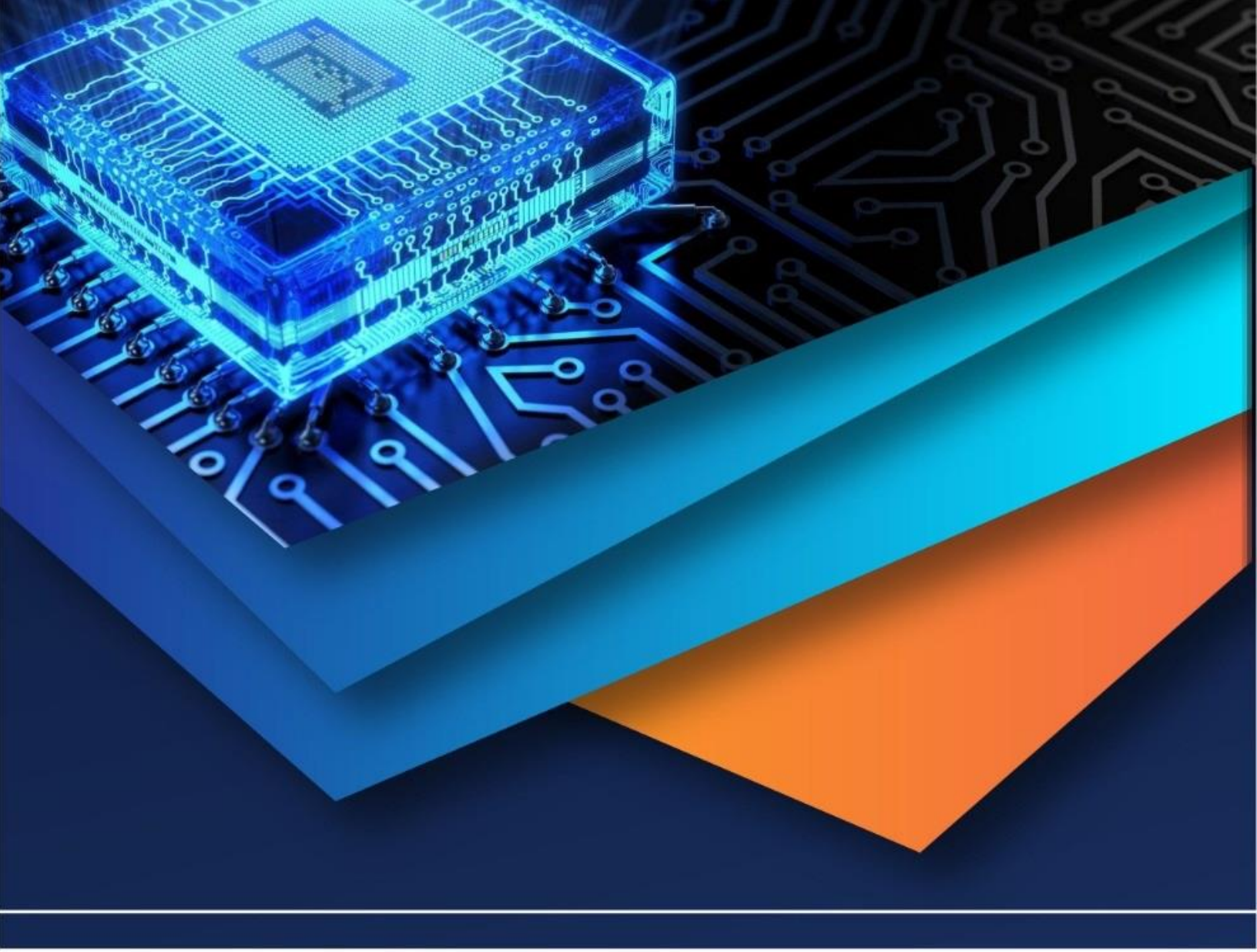

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