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Experimental Study on Concrete Made of Recycled Coarse Aggregate for Sustainability

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Abstract: ***In the construction industry, sustainable development has become a major concern over the years mainly due to the waste produced during construction, but more significantly, during demolition or destruction of large concrete structures. Due to the day-by-day increasing amount of demolished concrete waste, the idea of recycling such waste to produce aggregate for reuse in construction has been increasingly encouraged, thereby promoting the use of a recycled coarse aggregate as a substitute for the natural coarse aggregate. Reusing the aggregates obtained from demolished waste concrete not only conserves natural virgin aggregate but also reduces the need for landfills, decreases energy consumption and also lead to cost savings.***

In this study, experimental investigations were based on recycled coarse aggregate (RCA) obtained from crushing waste concrete found at the B.I.T. Sindri campus, Dhanbad, Jharkhand, India. The major focus of the research was obtaining the 28-day compressive strength for concrete with varying RCA content of 0%, 25%, 50%, 75%, and 100%. A total of five mixes with water-cement ratio of 0.44 were utilized for this purpose. The experimental results show that fresh natural coarse aggregate has the highest slump value, thereafter it starts deceasing with increasing the content of recycled coarse aggregate. There was a trend of decreasing strength of the 28th day compressive strength test with increase in the RCA content. However, the 50% RCA concrete mix produced very similar compressive strength to that of the 100% natural coarse aggregate concrete.

Keywords: Recycled aggregate, sustainable development, natural aggregate, concrete waste, compressive strength, slump.

I. INTRODUCTION

Cement concrete is most important material for construction industry. Basically, the concrete consists of cement, fine and coarse aggregates, these all are mixed with the help of water. In the present scenario for making concrete there is a very acute shortage of good quality aggregates. Hence the concrete industry people are looking towards alternative material for aggregates. Now a day the researchers are focusing on recycled aggregate to establish as an alternative material for aggregates. To minimise the problem of overload of waste material, it is a good step to use the recycled aggregates provide that the desired final product will meet the standards. Construction and demolition removals have also emerged as a problem in India. Indian construction industry today is amongst the five largest in the world and at the current rate of growth, it is slated to be surrounded by this century. The management of construction and demolition waste is a major concern due to increased quantity of demolition rubble, systematic shortage of dumping site, increase in cost of disposal and transportation and above all the concerns about environment degradation. The increasing problems associated with construction and demolition waste has led to a rethinking in develop countries and many of these countries have started.

II. OBJECTIVE

A. To investigate and improve the strength of recycled aggregate concrete.
B. The earth surface can be saved, and ecological disturbance will be reduced.
C. Best tool that can be adopted for effective solid waste management.
D. To emphasis reduce, recycle, and reuse concept in current construction field.
E. The problems of disposal and maintenance cost of land filling can be reduced.
F. Due to use of recycled aggregate in construction, energy and cost of transportation of natural resources and excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.
G. To reduce the demand of natural aggregate.

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III.LITERATURE REVIEW

1) *Legae M. Ngwenya et al. (2015) [1]:* found that with increase in RCA content, there is in broad terms a decrease in compressive strength. For the water-cement ratio of 0.45, the reduction for an RCA content of 100% is about 13.7% relative to the control; the corresponding value at a water-cement ratio of 0.5 is 15.3%. Additionally, the concrete specimens with 50% RCA contents give very similar compressive strengths at 28 days as those of the control specimens with 0% RCA, for both water-cement ratios utilized in the study. This demonstrates that concretes containing up to 50% RCA replacement content have potential as substitutes for natural coarse aggregate concrete. The presence of the old adhered cement paste in RCA contributes significantly to its higher water absorption capacity as compared to natural coarse aggregate concrete.
2) *Biradar Goudappa (2015) [1]:* found out based on the results obtained from the experiment the test results showed that the compressive of the recycled aggregate concrete is found to be lower than the natural aggregate. The strength of recycled aggregate concrete can be improved by the water and acid treatments. Recycled aggregate treated with nitric acid displayed the decent result compared to the hydrochloric and sulphuric acid and from economical point of view; water and acid treated recycled aggregates can be used in place of natural aggregates for temporary structures.
3) *Chetna M. Vyas (2013) [2]:* analysed the compression test result which indicates an increasing trend of compressive strength in the early age of the concrete specimens with 60% recycled aggregates. However, it shows that the strength of recycled aggregate specimens gradually increases up to 40% replacement of recycled aggregate & then it decreases at the 100% replacement of recycled aggregate after 28 days. The target strength for M20, M25, and M30 grade is respectively 26.6Mpa, 31.6MPa and 38.25MPa that are achieved for all the specimens tested in the study. The results also show that the concrete specimens with 40% replacement of recycled aggregate get the highest strength when compared to the concrete specimens with different percentage of recycled aggregate. From the obtained result, it is possible to use 40% recycled aggregate for higher strength of concretes. Hence the recycled aggregate can be used in concrete with 40% replacement of natural coarse aggregate.
4) *Patil Sudhir et al. (2013) [3]:* investigated that the compressive strength of concrete containing 50% RCA has strength in close proximity to that of normal concrete. Tensile splitting test shows that concrete has good tensile strength when replace up to 25-50%. The strength of concrete is high during initial stages but gradually reduces during later stages. Water absorption of RCA is higher than natural aggregate. Due to lack of treatment process for RCA adequate strength is not achieved but by applying more advanced and sophisticated treatment process the strength can be improved.

IV.EXPERIMENTAL SETUP AND MATERIALS

A. General

In this work, a comprehensive experimental schedule is being formulated to achieve the objective. The entire experimental work is classified into the following steps:

1) Collection of materials.
2) Laboratory test of materials.
3) Selection of Mix design.
4) Test on Natural Coarse Aggregate (NCA) Concrete.
5) Test on Recycled Coarse Aggregate (RCA) Concrete.

B. Cement

The cement used in the concrete was Portland slag cement with trade name ‘ACC CEMENT’. Physical properties of the cement have been obtained from the tests carried out in the Structure laboratory of B.I.T. Sindri as per specification laid down in IS: 455-1989. The chemical properties of cement have been obtained from IS: 455:1989. To find out the Physical properties, the tests which were conducted on cement are Consistency, Initial and Final Setting time, Fineness test, Soundness, Specific Gravity and Compressive Strength test. Their obtained results are presented in Table 1:

Table 1 Physical properties of cement

Sl. No.	Properties	Result
1	Consistency	32%
2	Initial Setting time	92 min
3	Final Setting time	285 min
4	Soundness	3 mm
5	Specific Gravity	3.2
6	Fineness	3%
7	Compressive Strength (28 days)	33.45

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C. Fine Aggregate

The natural fine aggregate (NFA) used for the experimental work was locally obtained (Barakar river) and conformed to grading zone II as per BIS (IS: 383-1970). The NFA was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. NFA act as filler in concrete. It is commonly known as sand and its main constituent is silica. The NFA is air dried to obtain saturated surface dry condition to ensure the water content ratio is not affected. The Sieve Analysis of sand is carried out to know the zone of the sand. The other test which were performed on NFA are Specific gravity, Fineness Modulus, Water absorption and Moisture content. Results of these tests has been presented in Table 2.

D. Natural Coarse Aggregate

Machine crushed granite obtained from quarry was used as a coarse aggregate. Coarse aggregate forms the main matrix of the concrete, whereas fine aggregate form the filler matrix between the coarse aggregate. Locally available Natural aggregate (NCA) having the maximum size 20 mm was used in the present work. The 20 mm aggregates were first sieved through 20 mm sieve and then it was washed to remove dust and dirt and was dried to surface-dry condition to ensure the water cement ratio is not affected. Test sieves conforming to BIS (IS: 460-1962 Specification of 80 mm, 40 mm, 10 mm, 4.75 mm) were used for sieving. The other test which were performed on NCA are Specific gravity, Fineness Modulus, Water absorption and Moisture content, Impact value and Crushing value. All these properties may have considerable effect on the quality of concrete in fresh and hardened states. Results of all these tests are presented in Table 2.

E. Recycled Coarse Aggregate

The recycled coarse aggregate (RCA) obtained from the demolished waste concrete from the buildings of B.I.T. Sindri Campus was used in the entire experimental work. The RCA obtained from waste concrete consists of adhered mortar on original aggregate. This results in more water absorption in the aggregate compared to natural coarse aggregate. Impact value and Crushing value were found to be greater in RCA as compared to NCA which implies lesser strength of the old used aggregates. It is necessary to know the specific gravity and water absorption of the aggregate in order to determine the mix proportions of concrete. RCA having the maximum size 20 mm was used in the present work. Accordingly, tests which were carried on NCA are also performed on RCA as per the procedure given in IS: 2386-1963 (Part 3) and the result are presented in Table 2.

Table 2 Physical properties of aggregates

Sl. No.	Tests	Fine Aggregate	Natural Coarse Aggregate	Recycled Coarse Aggregate
1	Moisture content	0.4%	0%	0%
2	Water absorption	1.2%	0.95%	2.63%
3	Specific gravity	2.62	2.72	2.52
4	Fineness Modulus	2.56	7.02	6.98
5	Crushing Value	---	28.32%	34.33%
6	Impact Value	---	19.20%	28.34%

F. Selection of Mix Design

M25 grade of concrete has been selected for this test with three different mix design M1, M2 and M3 were prepared for three different water-cement ratios as per IS: 10262-2009. M_2 achieves the target strength of M25 and its slump comes in the range of medium degree of workability as per IS 456. As per IS 456 in this range of workability, we can use this concrete in conditions of heavily reinforced sections in slab, beams, columns, pavement etc. So we select the mix design M_2 for this project work. The mix ratio of M_2 is 1:1.42:2.86. A total of five mix design were prepared with different RCA content, i.e 0%, 25%, 50%, 75% and 100%.

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G. Test on Concrete

1) *Workability (Slump):* The properties of fresh concrete are assessed by workability in terms of slump value. To check the slump value of fresh concrete in the range of 50-75 mm, the slump cone test is conducted on all concrete mixes. The slump cone is specified by BIS (IS: 7320-1974) is used to measure the slump of fresh concrete. The slump cone is placed on a smooth surface (metal base plate) and filled with concrete in three layers, each layer is compacted uniformly by 25 blows with a standard 16 mm diameter tamping rod, and the top surface is struck off by means of sawing and rolling motion of the tamping rod. The mould is lift slowly without shaking and the unsupported concrete is the slump. Height of slump is measured. Slump test apparatus is shown in Figure 1.

Figure 1 Slump Test apparatus

2) *Compressive Strength:* The compressive strength is determined using 2000 KN compression testing machine in accordance with BIS (IS: 516-1959). The compressive strength test was conducted on 150 mm size of cube after 7 and 28 days, adopting wet curing process. Three cube specimens were tested after each curing period of 7 and 28 days. A total of 6 cube specimens were tested for compressive strength for each mix. The test result is discussed in Chapter IV. Compression testing machine is shown figure 2.

Figure 2 Compression Testing Machine

3) *Split Tensile Strength:* The split cylinder test is performed to find the tensile strength of a cylindrical concrete specimen. The split tensile strength of concrete was determined after 7 days and 28 days of curing on cylindrical specimens of 150 mm diameter × 300 mm height using 1000 KN compression testing machine as per the procedure given in BIS (IS: 5816-1999). The test results are discussed in the next chapter.
4) *Flexural Strength:* This test was performed in accordance with BIS (IS: 516-1959) on prisms of size 100 × 100 × 500 mm after 28 days of water curing using 200 KN universal testing machine. The specimen was supported on two roller support spaced at 400 mm centre to centre. The load was then applied at rate of 0.7 N/mm2/min through two similar rollers mounted at third point of the span till the failure occurred. The flexural strength is expressed as modulus of rupture and it is calculated based on the appropriate expression in code. Three samples are used for each mix of concrete and the average result is reported in next chapter.

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V. RESULTS AND DISCUSSION

In this study, the properties of concrete with various proportions of locally available constituents are investigated. Concrete contains cement, water, fine aggregate, coarse aggregate (Recycled and Natural). With the control concrete, i.e. 0%, 25%, 50%, 75% and 100% of the natural coarse aggregate (NCA) is replaced with the recycled coarse aggregates (RCA). Three cube samples were cast on the mould of size 150x150x150 mm for each 1:1.42:2.86 concrete mix with partial replacement of coarse aggregate with w/c ratio as 0.44. After about 24 h the specimens were de-moulded and water curing was continued till the respective specimens were tested after 7 and 28 days for compressive strength and workability tests.

A. Workability (Slump)

The variation of workability for Natural Coarse Aggregate Concrete and Recycled Coarse Aggregate Concrete with different proportions i.e. 0%, 25%, 50%, 75% and 100% are presented in Table 3 and Figure 3.

It is observed that the Slump value of NCA Concrete is the highest among the five mixes with the value gradually decreasing with the increase in introduction of RCA in the concrete mix. This is due to the rough surface and higher porosity of adhered mortar on to the recycled coarse aggregates which results in higher absorption of water.

Table 3 Slump Test result

RCA Content	0%	25%	50%	75%	100%
Slump (mm)	82	73	70	66	54

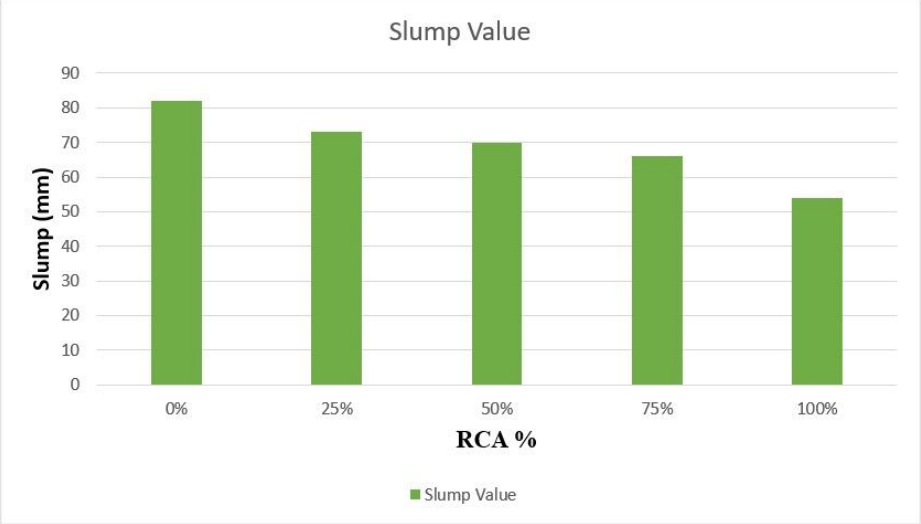

Figure 3 Slump Test result variation

B. Compressive Strength

The variation of compressive strength values with different RCA proportions are presented in Table 4. Figure 4 show the variation of strength development of concrete with different curing periods. From the results, compressive strength of concrete with 100% NCA has the highest 7-day and 28-day strength which reaches 23.33 MPa and 34.60 MPa respectively followed by 50% replacement of RCA. Concrete with 100% RCA has the least compressive strength with the reduction in strength for the RCA content of 100% is about 22.4% relative to the control specimen with 0% RCA content. The compressive strength of recycled concrete with 50% replacement of RCA is in close proximity with that of the control concrete (100% NCA). The main reason of strength reduction may be the adhered mortar to the RCA and other non-aggregate material present with it. This can be avoided by using proper cleaning techniques for the recycled aggregate and casting methods under highly skilled supervision.

Table 4 Compressive Strength test result

RCA content	0%	25%	50%	75%	100%
7 days strength	23.33	20.93	22.75	18.74	18.04
28 days strength	34.60	32.23	33.56	28.11	26.83

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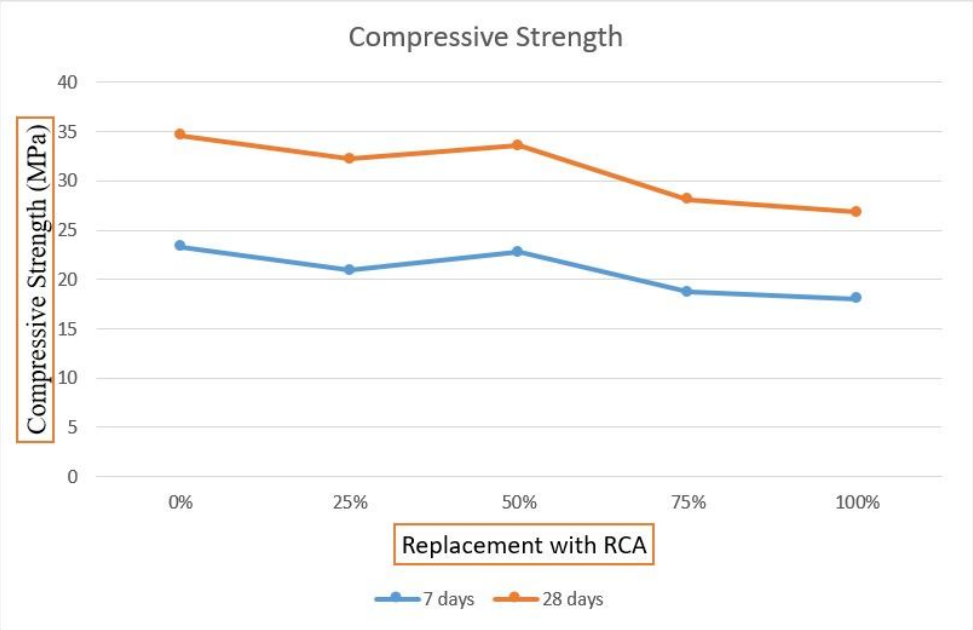

Figure 4 Variation in Compressive Strength at different RCA content

C. Split Tensile Strength

The variation of Split tensile strength values with different RCA proportions are presented in Table 5. Figure 5 show the variation of strength development of concrete with different curing periods. From the results, split tensile strength of concrete with 100% NCA has the highest 7-day and 28-day strength which reaches 2.66 MPa and 3.79 MPa respectively. Concrete with 100% RCA has the least strength with the reduction in strength for the RCA content of 100% is about 14.1% relative to the control specimen with 0% RCA content. The split tensile strength of recycled concrete with 25% replacement of RCA is in very close proximity with that of the control concrete (100% NCA), after which it gradually starts decreasing with increase in RCA content. Concrete with 50% RCA shows split tensile strength value of 3.6 MPa that is just 5.5% lesser as compared to 0% RCA.

Table 5 Split Tensile Strength test results

RCA content	0%	25%	50%	75%	100%
7 days strength	2.66	2.60	2.62	2.52	2.40
28 days strength	3.79	3.74	3.6	3.46	3.25

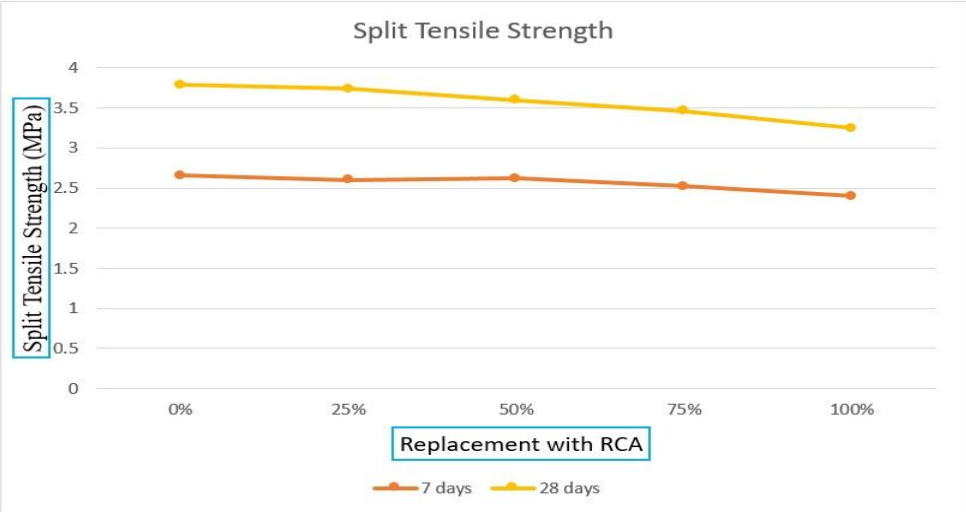

Figure 5 Variation in Split Tensile Strength at different RCA content

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D. Flexural Strength

The variation of flexural strength values with different RCA proportions are presented in Table 6. Figure 6 show the variation of strength development of concrete with different curing periods. From the results, flexural strength of concrete with 100% RCA has the least strength with the reduction in strength for the RCA content of 100% is about 10.8% relative to the control specimen with 0% RCA content. The flexural strength of recycled concrete with 25% replacement of RCA is in very close proximity with that of the control concrete (100% NCA). Concrete with 50% RCA shows flexural strength value of 4.62 MPa that is just 3.75% lesser as compared to 0% RCA. Strength value of 100% RCA concrete is approximately about 90% of the 100% NCA concrete.

Table 6 Flexural Strength Test results

RCA content	0%	25%	50%	75%	100%
28 Days Strength	4.80	4.76	4.62	4.53	4.38

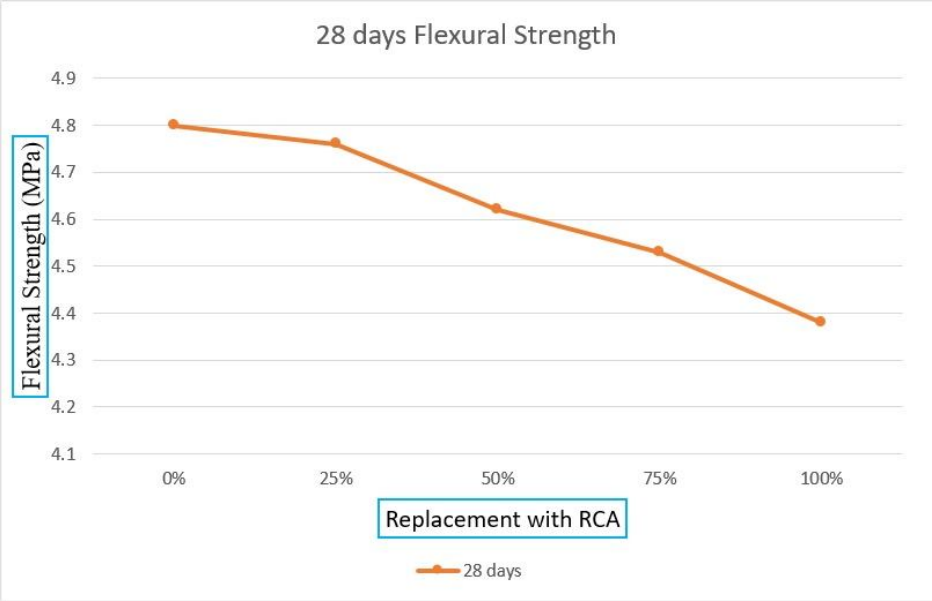

Figure 6 Variation of Flexural Strength at different RCA content

VI. CONCLUSIONS

It is very important to research on the usage of waste construction as the materials waste is gradually increasing with the increase of population and increasing of urban development. On the basis of our comparative analysis of test results of the basic properties of concrete with five different percentages of Recycled coarse aggregate content (0%, 25%, 50%, 75% and 100%), the following conclusions are made:

A. The slump test indicates a decreasing trend of workability when the percentage of recycled aggregate are increased. The highest slump obtained was 82mm and the lowest slump was 54mm. The workability was good and can be satisfactorily handled for 0% recycled aggregate to 100% recycled aggregate.

B. The compression test result indicates decreasing trend of compressive strength in the early age of the concrete (28 days. The compressive strength of recycled concrete with 50% replacement of RCA is in close proximity with that of the control concrete (100% NCA). Therefore, RCA upto 50% replacement can be used in construction works with satisfactory results.

C. The split tensile test result also indicates decreasing trend of strength in the early age of the concrete (28 days). Concrete with 50% RCA shows split tensile strength value of 3.6 MPa that is just 5.5% lesser as compared to 0% RCA. Thus it can be concluded that RCA upto 50% is safe to use.

D. The flexural strength test result shows similar decreasing trend of strength in the early age of the concrete (28 days). The flexural strength of recycled concrete with 25% replacement of RCA is in very close proximity with that of the control concrete (100% NCA). Strength value of 100% RCA concrete is approximately about 90% of the control mix (100%NCA) concrete.

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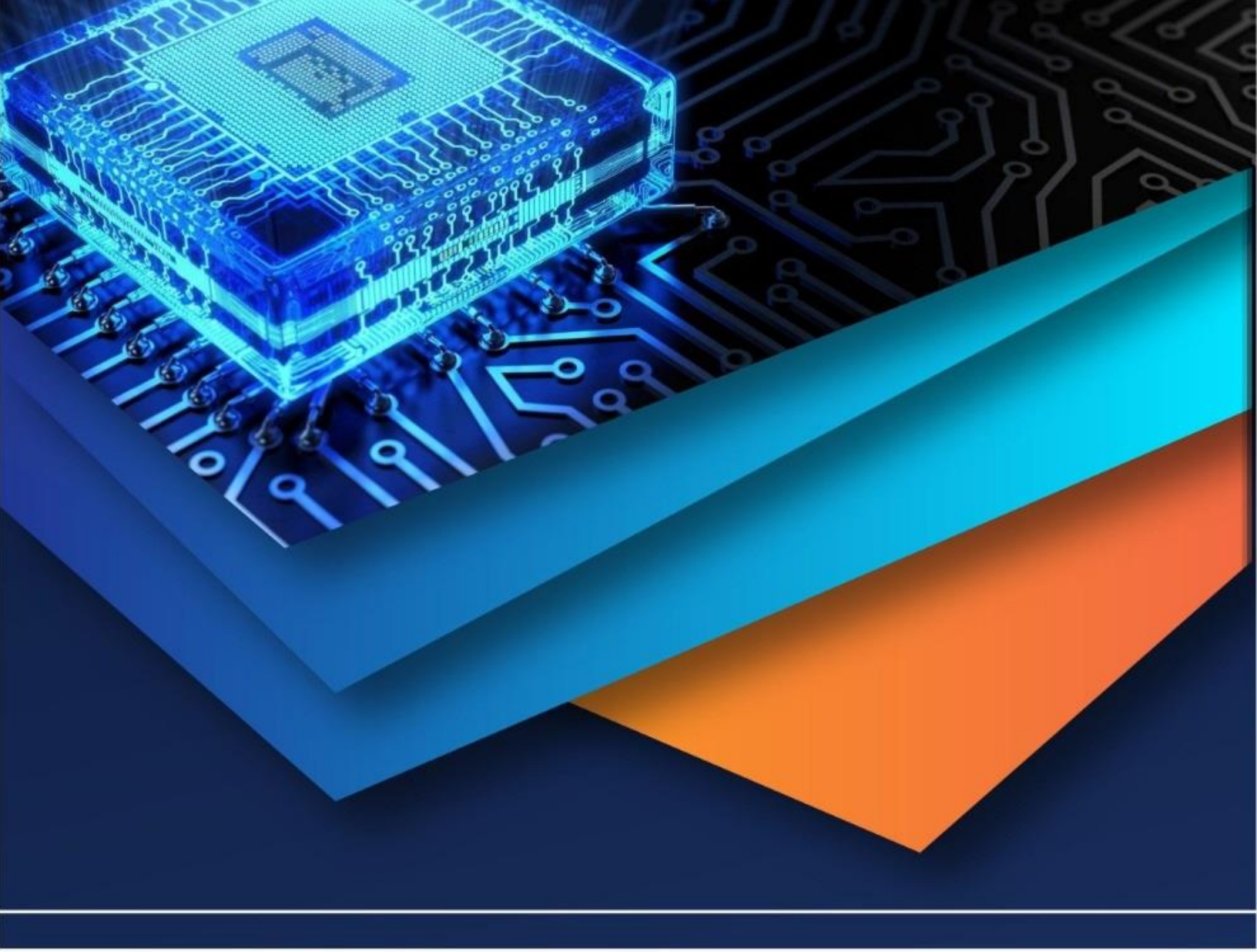

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