Study on Partial Replacement of Natural Aggregate Concrete (NAC) With Recycled Aggregate Concrete (RAC)

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Abstract. This paper is about the use of the recycled aggregate concrete (RAC) instead of using the normal conventional concrete to reduce the usage of naturally available aggregate and it’s an alternate to preserve our natural resources, utilize the construction and demolition waste (C&D). The upgradation of living life needs a replacement and new design to remove or rehabilitate the old buildings. Will lead to tones of C&D wastes; there is limited place to dispose it. Main reason is to tackle the problems based on the waste management that has become one of the tremendous problems that cannot be resolved. The squanders that can be reused once on the off chance that it is utilized is generally best in this colossal populace society don’t have the foggiest idea where to dump every one of these squanders. Instead of disposal, our government along with researchers started utilizing this waste again in the construction in the form of Recycle aggregates like fine particle and Recycle concrete aggregate. Most of the states in India having plants in disposal area to recycle this C&D waste. From the studies it says that recycle aggregate concrete can be used for M25, M30, M35, M40 and also use in Self compacting concrete. In this paper we did experimental studies on Recycle aggregate concrete (M25) near area has been used and identify its basic properties. The cement is supplanted with reused coarse total (RCA) of two unique proportions (40, 60\& 80) and their compressive quality and brace rigidity of the solid are tried. The outcomes show that the RCA of proportion 80 \% has higher quality than the solid with half substitution.

1. Introduction

Solid waste management is perhaps the most concerning issue that is raising its way to its pinnacle. In all cases the substance we are utilizing will be a waste item. Hence it is wise to utilize the substances that can be reused when its need is finished. Thus, this is pertinent in structural designing fields as well. Concrete has been the most famous and indispensable part for the development of the structure. In any case, it got famous simply after the development of the concrete now it has been the significant restricting part and quality creating substance for the structure. The compressive quality of the solid
differs from 25 MPa to 40 MPa. Because of its effective utilize the solid has been tried for its physical properties, synthetic properties and imperviousness to fire by numerous specialists [1]. Attributable to over abuse of the fixings that are required for the solid and in the other hand the waste cement acquired after the destruction of the structures there is a deficiency for the solid creation. The solid is utilized the normal fine total (waterway sand) which has been at the edge of misuse. Presently the solid is likewise setting off to the way of annihilation. At a similar period the destruction of any structures prompted the wastage of the solid. Thus the reused total cement is utilized in specific proportions with the ordinary regular cement so as to lessen the over utilization of the solid and to reuse the waste cement. At the point when the RAC is checked for its quality, the trait of the reused total cement is unique in relation to the parent concrete because of the way that the parent concrete is intended for its solid and high quality and usefulness of the solid[1,2].

The typical solid total is squashed by means of smashing machine. The devastating encourages just the uncontaminated solid that ought to be liberated from dampness. The other metal rebars are acknowledged supposing that there are any issues the metals can be expelled with the magnets or it very well may be dispensed down for reuse. And furthermore, the way toward pulverizing done at the building site diminishes the expense of the development and transportation season of the solid to the site is decreased and the contamination is additionally decreased. The devastating is finished by the size of the coarse total required. The support done ought to be expelled before checking the nature of the total. The RAC ought to have a devastating sound and should comprises of clean waste cement by at any rate 95% of the heaviness of the solid with having lower than 1% of the mass.

These totals can likewise be utilized as the dry total for the new creation of the solid in the event that it is liberated from contaminants. Likewise, these cements can be broken can be utilized as a base layer for black-top asphalts through a procedure called Rubblization. The US Federal thruway method utilizes along these lines to build the new expressways from the losses of the old obliterated parkways. Enormous pieces can be utilized for riprap asphalts exceptionally productive for controlling the stream bank disintegration. The benefits of the RAC are that it spares the land space; utilizing reused rock decreases the rock mining. In this universe of improving the manageable properties it is basic to utilize the reused total cement. The RAC has perceived by the LEED by the green structure rating framework. There is another perspective that the carbonation creation during the solid pounding. The territories that are not more carbonated will retain the CO2 which will lead to result of the solid. Different classes of RAC is utilized, for example, , class H-utilized for as the supplanting of new cement with an ostensible quality of 45 MPa, class M-the individuals ought not be developed that it ought not be directed to freezing and drying and defrosting action, class I-utilized in levelling, refilling of the solid[1].

1.1.Literature Review:

Geolin Suganth et al has published an article based on the behaviour of the RAC in bending and torsion. The RC beams are tested with the RAC beams. The outcomes were from the perceptions that uncovered that the heap bearing limit of the RAC is practically minimal equivalent to the RC shafts. The firmness of the customary cement is more than that of the RAC. The avoidance of the RAC shafts is more than that of the customary pillars both in twist and bowing. He proposed that the investigation on RAC with various kinds if filaments are required and fine total can be supplanted with the RAC powder (squashed)[1].

Miren Etxeberria et al has distributed an article on the hardened property consequences of the solid. They have utilized the four solid blends with the supplanted proportions of about 0%, 25%, 50%, 100% of the reused coarse total and the testicles for the compressive quality, part rigidity are made. The outcomes got shows that the RCA replacement under 25% barely influences the shear quality of the RC bars[1].
Gonzalez-Taboada et al has distributed an article on the strength of the concrete based on the compression database analysis. He recommended that when the water absorption amount is low in RAC unfavourably influence the usefulness and compressive quality of the solid and simultaneously the water retention substance ought not to be excessively low (at least 5%). By knowing the RCA and the blending methodology impacts the quality of the solid. The solid has been supplanted in the level of 30% and half of the RCA. The half substitution shows the most elevated quality of the solid[2].

Hat C.T et al has distributed an article on the strength of the concrete reveals that RCA can be used as a sustainable product. Single size RCA (4-10 mm) joined with the single normal total (10-120 mm) can be utilized for the better control creation. The 30% to 40% of the supplanting with the characteristic coarse total will create alluring consequences for the solidified properties of the solid. It is additionally practical and prudent [5].

Mirjana Malesev et al has distributed an article on the examination of the concrete reveals that RCA have influence on the quality of the concrete. The solid uncovers that the RCA have impact on the nature of the solid. In the event that the nature of the solid is acceptable it tends to be utilized for the creation of the new concrete. Shrinkage of the solid relies upon the measure of the RAC utilized. Over half substitution of the RAC will bring about more shrinkage when contrasted and the traditional cement. Compressive burdens rely upon the amount of the solid utilized. The compressive worry of solid increments up to 25% when the amount of the RCA is expanded up to 100% [5]

1.2 The Main Objective:

Typically the particular gravity of the totals ranges from 2.5 to 3 in the street developments with a normal of about 2.68. despite the fact that the higher the particular gravity the higher the quality of the solid it isn't right to finish up the reasonableness of the total without the mechanical properties of the total, for example, total pounding, effect and scraped spot esteems .it is the proposed that the water retention limit ought not be more than 0.6 per unit weight. According to the investigation of the exploration papers it is discovered that the particular gravity of RCA isn't more noteworthy than the ordinary total utilized. The thickness of RCA is likewise lesser than that of the typical total. The water retention limit of the RAC is higher.

2. Material and Methodology:

2.1 Material Investigation:

Cement is binding material used for construction purposes which sets, adheres and hardens other materials and combines it together. OPC (Ordinary Portland Cement) have been used.

2.1.1 Tests on Recycled Aggregate:

Recycled Coarse Aggregate (RCA):

A. Sieve Analysis

| Sieve size | Mass retained | Percentag e of mass | Cumulative % retained | % finer |
|------------|---------------|---------------------|-----------------------|---------|
| Table 1.   |               |                     |                       |         |
### Table 2.

Particle size distribution of Natural Coarse Aggregate

| Sieve size (mm) | Mass retained (kg) | Percentage of mass retained (%) | Cumulative % retained | % finer |
|-----------------|---------------------|-------------------------------|-----------------------|---------|
| 40              | 0                   | 0                             | 0                     | 100     |
| 20              | 0.59                | 1.15                          | 1.15                  | 98.85   |
| 16              | 1.24                | 28.5                          | 29.65                 | 70.35   |
| 12.5            | 1.68                | 33.45                         | 63.1                  | 36.9    |
| 10              | 0.34                | 7.75                          | 70.85                 | 29.15   |
| 4.75            | 1.55                | 28.7                          | 97.59                 | 2.41    |
| 2.36            | 0.041               | 1.61                          | 99.2                  | 0.8     |
| Pan             | 0.09                | 0.086                         | 100                   | 0       |

**Figure 1.** Graphical representation of (a) Particle size distribution of NCA and (b) Particle size distribution of RCA
From the outcomes acquired from the chart that reused coarse total (RCA) demonstrated a very much reviewed diagram. So it tends to be recommended that the RCA can be utilized as halfway trade for the NCA subsequently the utilization of the new normal coarse total is decreased along these lines lessening the overabundance use and the destruction squanders is reused.

Table 3.
Comparison on Natural Coarse Aggregate (NCA) with Recycled Coarse Aggregate (RCA)

| S.NO | Property                  | NCA   | RCA  |
|------|---------------------------|-------|------|
| 1    | Specific Gravity          | 2.84  | 2.69 |
| 2    | Water Absorption (%)      | 1.668 | 1.32 |
| 3    | Bulk Density(kg/m³)       | 1797.6| 1657.5|
| 4    | Crushing Value (%)        | 24    | 27.9 |
| 5    | Impact Value (%)          | 19.44 | 24.3 |
| 6    | Abrasion Loss (%)         | 28.9  | 36.2 |

RCA obtained from squashed solid waste is typically unique in relation to NCA since the first total particles are encircled by old concrete mortar. The nearness of the followed concrete mortar makes RCA to yield unexpected physical and mechanical properties in comparison to the NCA. The presentation of RCA is likewise changing relying upon the nature of the solid waste where they are delivered from. The most widely recognized properties that portray the physical and mechanical properties of RCA and NCA, which are utilized to create all the solid examples considered in this test study, were tried[2].

2.2 Discussion on physical properties of RCA in detail:

Specific gravity:
Specific gravity of total is the proportion of the thickness of the total to the thickness of water. This property is normally applied for deciding the volume involved by the total in solid blend. There are three unique sorts of specific gravities dependent on how the volume of water porous voids (or pores) inside the totals are thought of. These are (I) specific gravity (OD): processed based on broiler dry totals; (ii) specific gravity (SSD): examined based on soaked surface-dry totals; and (iii) evident specific gravity: determined based on immersed totals. The particular gravities (OD, SSD, and clear) of the RCA were 2.17, 2.35, and 2.69 respectively. The test outcomes showed that the particular gravity (OD) of the RCA is near the base explicit gravities of customary totals. The most normally used characteristic totals have explicit gravities that change from 2.2 to 3.0. A low specific gravity may demonstrate high porosity and subsequently helpless sturdiness and low quality. It likewise enormously impacts the thickness and quality of cement. The void proportions of the RCA and the NCA were likewise analyzed as per ASTM C29/C29M.

Water absorption:
Water absorption is the amount of moisture absorbed in the aggregate. The water absorption capacity is based on saturated surface dry condition and oven dried condition mentioned that the amount of water in a concrete mix has direct effect on the setting time and compressive strength
of concrete. The absorption test decides the all out pore volume by estimating the measure of water that the total particles can retain into its pore structure. This is because of the way that the measure of the absorbed water depends overwhelmingly on the plenitude and the coherence of the pores in the total molecule. It is one of the most crucial properties required for structuring solid blend. The pore structure of total administers the microstructure of the solid, which thusly impacts the new and the solidified solid qualities. In reality, it is a verifiable truth since around 75% of the solid volume is involved by totals. The directed ingestion test result affirmed that the measure of water consumed by the RCA was 1.32, which is lower than that by the NCA used in this test study. It indicates that it has the low water absorption capacity so that the water-cement ratio will be less when compared with the conventional aggregate[6]

Bulk density:
The bulk densities of the RCA and the NCA were resolved in compacted and free conditions. The compacted mass thickness for the RCA was 1657.5 kg/m3, though that for the NCA was 1797.6 kg/m3 separately. It very well may be seen from these test esteems that the compacted and mass thickness of the RCA are 7.79% not exactly those of the NCA, individually. The higher the mass thickness of the coarse total means that the nearness of less voids to be filled by little particles, for example, sand and concrete. In spite of the fact that the RCA acquired less mass thickness contrasted and the NCA, it is in the scope of typical weight total's mass thickness. It can decrease oneself load of the solid. Subsequently it lessens the danger of the quake catastrophes.

Crushing strength:
The crushing strength tests on RCA had higher squashing values than that of NCA, and warming additionally caused an augmentation in smashing estimation of NCA. So also, it has been found by another examination that, when the water/concrete proportion of RAC is lower than that of the first concrete, the quality of RAC might be constrained by quality of the first concrete, and the most vulnerable point in RAC is RCA and specifically the appended mortar. There is an expansion in the level of pulverizing quality of the RCA by 16.25% to that of NCA. Henceforth it gives the higher compressive quality, have high modulus of versatility, high rigidity for example gives the high solidified properties if concrete.

Impact test value:
The impact strength of the RCA likewise has the higher effect quality of the solid. As same as that of the devastating estimation of the total, the effect estimation of the total is additionally high showing the adequate solidified properties of the solid. The effect estimation of the coarse total of RCA is 25% higher than that of the NCA. Anyway it can't be supplanted totally with the reused total cement [5].

Abrasion loss test:
The durability and scraped spot attributes of the RCA and the NCA were evaluated by the L.A. scratched spot test according to ASTM C131-06. This test merges the patterns of consistent misfortune and scratched region and outfits results which show a relationship with the genuine wear of the aggregate. A case of absolute particles hung on the sifter size proposed by the standard was put inside a turning steel drum which contains a foreordained number of steel circles. As the drum turns, the complete particles are presented to scratched zone and beating. The drum continues turning for a foreordained number of revolts. By then after, the complete was taken out from the drum and sieved using a comparative sifter. The complete hung on the sifter was checked, and the complexity between this weight and the principal weight was conveyed as a rate to obtain the L.A. scratched spot setback. The assessment of the L.A. scratched spot loss of the NCA was 28.9%, while the RCA was 36.2%. It suggests that the RCA has less assurance from scratched spot than the NCA used in the work. It is
suitable for general advancement since its L.A. scratched spot hardship is well under quite far (45%) as shown.

![Graphical representation on Comparison of NCA and RCA](image)

**Figure 2.** Graphical representation on Comparison of NCA and RCA

2.3. Methodology:

(1) Demolished building concrete and some of the tested concrete cubes were taken

(2) They were crushed into smaller pieces with the help of hammer.

(3) And further the pieces are crushed with the abrasion machine and it is taken out. The moisture is removed and dried well.

(4) Aggregates were separated in different sizes through the sieve analysis.

(5) Gradation of 20mm were prepared and used.

![Manufacturing process of RAC](image)

**Figure 3.** Manufacturing process of RAC

3. Result Analysis and Discussion:

3.1. Hardened Properties of RAC:

3.1.1. Compressive Strength:
Compressive quality is characterized as the protection from disappointment under the activity of compressive powers. At the point when cement solidifies and increases adequate solidarity to help its own weight and development load.

Size of the block = 150 mm x 150mm x 150 mm

RCA: **40% Replacement** with NCA

| Table 4. |
| --- |
| Compressive Strength Test on the Specimens |
| (40% Replacement with NCA) |

| Days | Load KN | Compressive Strength N/mm² |
|------|---------|-----------------------------|
| 7    | 650     | 14.2                        |
| 14   | 720     | 19.8                        |
| 28   | 750     | 21.6                        |

RCA: **60% Replacement** with NCA:

| Table 5. |
| --- |
| Compressive Strength Test on the Specimens |
| (60% Replacement with NCA) |

| Days | Load KN | Compressive Strength N/mm² |
|------|---------|-----------------------------|
| 7    | 650     | 16.7                        |
| 14   | 720     | 20.77                       |
| 28   | 750     | 24.65                       |

RCA: **80% Replacement** with NCA

| Table 6. |
| --- |
| Compressive Strength Test on the Specimens |
| (80% Replacement with NCA) |

| Days | Load KN | Compressive Strength N/mm² |
|------|---------|-----------------------------|
| 7    | 650     | 16.2                        |
3.1.2. Split Tensile Strength:

Concrete is poor in elasticity. To quantify the quality is dreary. Consequently split tractable technique is utilized. Examples of chambers are utilized for the test. This test is uniform than other pressure tests. In this manner they got outcomes are like the real rigidity of cement.

| Mix Ratio (% Replaced With NCA) | Split Tensile Strength N/mm² |
|--------------------------------|-----------------------------|
| 40%                           | 2.25                        |
| 60%                           | 3.52                        |
| 80%                           | 3.73                        |

3.1.3. Flexural Strength:

When the concrete is subjected to bending both the compressive and tensile strength is developed. The strength per unit area is called as the flexural stress. The value of the modulus depends upon the dimensions of the beam and on the arrangements of loading.

| Mix Ratio (% Replaced With NCA) | Flexural Strength N/mm² |
|--------------------------------|-------------------------|
| 40%                           | 2.55                    |
| 60%                           | 3.412                   |
| 80%                           | 3.45                    |

From the outcomes got from the compressive, split tractable and flexural quality it is presumed that the outcomes are relatively low with that of the regular coarse total when the RCA is supplanted with 40% of the NCA. Anyway it demonstrated calculable quality at 60% substitution of RCA. Albeit 100% substitution can't work it achieved a normal quality when 80% of incomplete substitution is finished. Reality is that the quality of RAC is commonly low when contrasted and the first concrete. So the halfway supplanting of NCA with RCA gives a superior outcome which is one of the key hotspots for the reasonable turn of events and waste administration[7].
Note: The results of split tensile strength and flexural strength of specimen are based on the strength of the concrete after 28 days of curing.

4. Conclusion

(1) The compressive strength and the split tensile strength of the concrete (RAC) with the partial replacement with the NCA is comparatively high [2].

(2) From the results we can observe that the specific gravity of the RCA is less when compared to NCA. It means that the RCA can be used in light weight construction. Generally the specific gravity of the RCA should be higher than that of the water cement ratio to attain the higher strength of the concrete [4].

(3) However RCA can be partially replaced to control the disadvantage. And the water absorption quantity is less so the recycled aggregate concrete possess lower water cement ratio. Hence the consumption of the water will be less [3].

(4) The crushing value is high in RCA indicates that it is already used concrete hence it is used as partial replacement with the original concrete and hence it can be suggested that the RCA can be used as the best partial replacement material for the normal aggregate concrete.

(5) The compressive strength, split tensile and the flexural strength of the RAC falls down in the range between as that of the conventional concrete.

(6) But the RAC cannot be as more comfort as that of the conventional concrete. So the partial replacement of RCA with the NCA is the best and the economical way for the sustainable and smart technology in future.

(7) Compressive quality, parting rigidity, flexural quality of cement created from RCA is by and large lower than those of characteristic total cement. Nonetheless, higher quality can be accomplished if the solid delivered from RCA having the lower water concrete proportion contingent on the nature of the reused concrete from which the RCA is inferred.

(8) As it contains huge measure of old mortar, drying shrinkage and creep of RAC are 40% to 80% higher to control concrete produced using the normal aggregate.

(9) Chloride ingress tends to be more in RCA concrete [6].

(10) It shows better resistance to carbonation.

(11) Potential uses of basic evaluation concrete delivered are-establishment level lean solid, trail solid chunk, re divider solid boards, middle section solid board, and crash hindrance [5].

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