# Impact of Ureolytic Bacteria on Strength Properties of Recycled Aggregate Concrete

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***Abstract*— As the disposal of concrete waste poses the fewest environmental risks, the recycled coarse aggregate (RCA) concrete production technology is sometimes referred to as "green concrete." Regarding the water-to-cement ratio (w/c), the Indian standard suggests the desired mean compressive strength of conventional concrete. This study aims to propose a relationship between water cement ratios and compressive strength by examining the behavior of RCA concrete, which was made from two samples of parent concrete that were of various ages. The amount of recycling may have an impact on the RCA concrete's mechanical qualities. Examined are the effects of age and quantity of recycling on the RCA concrete's flexural strength, tensile splitting strength, air content, drying shrinkage strain, and capillary water absorption. The capillary water absorption increases suddenly while the compressive strength decreases gradually with the number of recycling, suggesting that additional recycle may not be advised. The addition of two ureolytic-type bacteria, Bacillus subtilis and Bacillus sphaericus, to RCA concrete to improve its characteristics. The purpose of the experimental studies is to assess how adding microorganisms to RCA concrete improves its drying shrinkage, capillary water absorption, and compressive strength. At the cell concentrations of $10^6$ cells/ml for the two bacteria, there is an approximate 20% and 35% increase in the compressive strengths of RCA concrete, respectively. When bacteria are added, RCA's drying shrinkage and capillary water absorption are both decreased.**

***Index Terms*— Recycled Aggregate Concrete, Concrete, Bacterial Concrete, Ureolytic Bacteria, RCA, Bacillus Subtillis, Recycled Coarse Aggregate**

## I. INTRODUCTION

Environmentally friendly engineering constructions are rare. Portland cement, which is used in the construction industry, is recognized to contribute significantly to CO2 emissions and environmental harm. Over the past 20 years, India has seen a sharp growth in the volume of construction. The total carbon footprint of the finished concrete product may be significantly decreased by substituting different kinds of supplemental cementing materials (SCMs), particularly SF and FA, for cement. The less Portland cement used in the manufacture of concrete, the less of an environmental impact the concrete industry will have.

### *A. Recycled Aggregate Concrete:*

Recycled coarse aggregate (RCA) from demolished concrete can be used in place of natural coarse aggregate (NCA) in fresh concrete to create RCA concrete. Numerous researchers that looked into the mechanical and physical characteristics of RCA concrete discovered that it had less mechanical strength than normal concrete with NCA. This is because of how much more RCA is porous than NCA and how much NCA needs to be replaced. Numerous studies have revealed that conventional concrete with NCA has superior mechanical and physical qualities than RCA concrete. The experimental results of employing microorganisms to improve the mechanical properties of RCA concrete are presented in the second section of this chapter. Further investigations were conducted on cement mortar alone in order to have a better understanding of the impact of bacterial mineral precipitation on the characteristics of RCA concrete. The outcomes of the properties of cement mortar with bacteria are shown in the final section of this chapter.

### *B. Bacterial Concrete:*

When concrete hardens, bacterial or self-healing concrete uses a bacterial response to fill up the gaps that have formed in the construction. We talk about the different kinds of bacteria, how they work, and how to make bacterial concrete. The use of technology in the modern era has raised the bar for construction standards. In order to achieve an excellent, cost-effective, and sustainable concrete construction, a variety of techniques, materials, and processes are employed. There are numerous solutions for this prevalent issue of developing cracks, both before and after the crack. Self-healing concrete, often known as bacterial concrete, is one of the corrective methods. Self-healing concrete is the result of a bacterial response in the concrete that allows cracks to fill in or mend themselves over time once it has hardened. It has been noted that in repeated dry and wet cycles, minor cracks in a structure with a width of 0.05 to 0.1 mm entirely seal.

Principle objective of this project involves the mechanical properties of concrete cubes by introducing a wire mesh by varying their orientations. In the present work analysis of mechanical properties of ferro-cement is done by taking various layers of the wire mesh such as single layered and double layered.

In this study we have considered wire mesh as it is soft and malleable, abrasion resistance and high tensile strength. We have compared the mechanical properties of the normal conventional concrete with the ferro-cement concrete.

Conventional concrete when used, over time passes it is subjected to cracks, spalling, wear and tear action, low tensile strength. These limitations of traditional concrete can be brilliantly reduced by introducing ferro-cement. Ferro-cement sheets are most commonly used as retrofitting material these days due to their easy availability, economy, durability, and their property of being cast to any shape without needing significant formwork.

This study briefly explains about the comparison of mechanical properties of conventional concrete to ferro-cement concrete. Our main objective of this project include the increase in performance of concrete which includes in study of compressive strength of Ferro-cement, Split tensile strength of Ferro-cement, Flexural strength of Ferro-cement

## II. METHODOLOGY

*A. Objectives of the Work:*

The primary goal of the current research project is to investigate the qualities of concrete created using RCA and potential improvements, as determined by a thorough examination of the literature. The following are the objectives to reach the main aim.

- To research how the w/c ratio and compressive strength affect RCA concrete's characteristics.
- Researching the use of microbes to improve the engineering qualities of RCA concrete.
- To Suggest an Optimum Percentage of Materials to Produce an Effective and Quality Concrete that can adopted for all possible Structural Applications.

*B. Methodology Adopted:*

To accomplish the aforementioned goals, the step-by-step process listed below is used.

- To assess the qualities of RCA concrete, prepare test specimens, make RCA from demolished concrete, and conduct various tests.
- Use a laboratory-cultivated bacterial culture to improve the characteristics of the RCA concrete.

*C. Materials:*

Cement is the main ingredient in manufacturing of concrete. The characteristics of concrete will b greatly affected by changing the cement content. The cement used in this project is Portland Pozzolana Cement (Ultratech) Confirming to IS 1489 - 1991. According to standard requirements, the sand is medium in texture and confirms to Zone-II. It was obtained from nearest Supplier.

*D. Recycled Concrete Aggregate:*

Aggregates of size more than 4.75mm are generally considered as coarse aggregate. RCA were gathered from two sources: (a) Old, abandoned concrete building Walls, Slab and Columns, and (b) broken concrete cubes and beams from a structural engineering lab (about 0 to 1 year old). Both sources' exposure conditions can be regarded as typical. Based on the source and age of the parent concrete, two categories are created from the collection of RCA samples. The Maximum Size of Aggregate was 20 mm.

*E. Ureolytic Bacteria:*

The bacteria that aid in the precipitation of calcium carbonate, B. subtilis and B. sphaericus. Having selected bacteria and confirmed their capability to precipitate the Calcium carbonate, the following procedure is used for cell culture for further studies.

- 500ml of nutrient broth for B. subtilis and Luria Bertani for B. sphaericus, broth is prepared in two fresh clean conical flask.
- After autoclaving the nutrient medium, bacteria is inoculated into it and incubated for 24hours at $37^0$C with constant shaking at 150 rpm.

The optical density test, which is based on the light scattering principle, is used to determine the cell concentrations in the bacterial culture mentioned above. To determine the cell concentration at 600 nm, follow McFarland's guidelines. When creating cement concrete, the cell culture is introduced to water after being diluted to the necessary concentrations.

Table -1: Properties of Cement

| Property | Result |
|---|---|
| Specific Gravity | 3.02 |
| Fineness of Cement | 276 $m^2$/kg |
| Normal Consistency | 32% |

Table -2: Properties of Aggregate

| Material | Specific Gravity | Bulk Density | Water Absorption |
|---|---|---|---|
| Natural Sand | 2.65 | 1650 Kg/$m^3$ | 0.5% |
| RCA | 2.50 | 1480 Kg/$m^3$ | 4.1% |
| Coarse Aggregate | 2.82 | 1720 Kg/$m^3$ | 1.2% |

## III. MIX DESIGN

Different concrete mixes with and without bacteria are taken into consideration in order to investigate the improvement of compressive strength of RCA concrete. After weight batching, the mix design is completed in accordance with the standard concrete design process found in IS: 10262-2019.

Table -3: Mix Proportions for RCA Concrete with Ureolytic Bacteria

| Mix Name | NCA Concrete | Bacterial Concrete | | | | |
|---|---|---|---|---|---|---|
| | | Control | BS 1 | BS 2 | BS 3 | BS 4 |
| Bacterial Cell Concentrations (cells/ml) | 0 | 0 | $10^1$ | $10^3$ | $10^6$ | $10^7$ |
| Cement (kg/$m^3$) | 372 | 372 | 372 | 372 | 372 | 372 |
| Sand (kg/$m^3$) | 582 | 560 | 560 | 560 | 560 | 560 |
| RCA (kg/$m^3$) | 1250 | 1133 | 1133 | 1133 | 1133 | 1133 |
| *W/C* ratio | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Water (kg/$m^3$) | 186 | 186 | 186 | 186 | 186 | 186 |

## IV. RESULTS AND DISCUSSIONS

*A. Influence Of RCA on Compressive Strength of Concrete:*

After 28 days of curing, all samples are put through a compression testing equipment to determine their compressive strengths. The Compressive Strength values of Concrete Mixes with RCA 1 and RCA 2 were given in the Table 4.

Table -4: Compressive Strength of Concrete with RCA 1 and RCA 2 at 28 Days

| 28 Days Compressive Strength of Concrete with RCA 1 & RCA 2 (Mpa) | | | | |
|---|---|---|---|---|
| Mix | W/C Ratio | | | |
| | 0.40 | 0.45 | 0.50 | 0.55 |
| Trial 1 (NAC) | 36 | 30 | 25 | 22 |
| Trial 2 (RAC 1) | 36.5 | 35.2 | 32.6 | 28.5 |
| Trial 3 (RAC 2) | 34.2 | 32.5 | 30.5 | 25.4 |

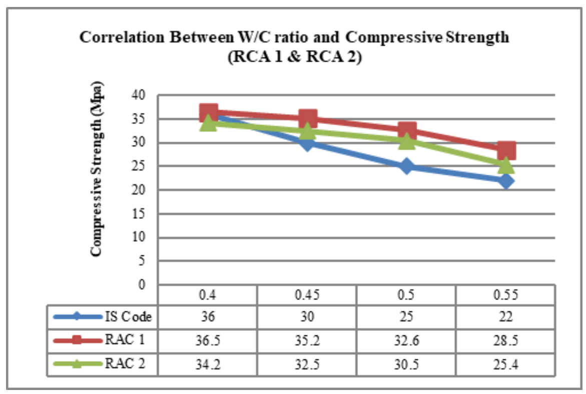


Fig. 1 Correlation between W/C Ratio and Compressive Strength using RCA 1 and RCA 2

*B. Drying Shrinkage of Concrete With RCA:*

All of the chosen RCA and NCA concrete samples' drying shrinkage has been examined in accordance with the described protocol. It is discovered that the drying shrinkage strain of RAC-1 and RAC-2 is, respectively, almost 2.0 and 2.7 times more than that of NCA concrete. The likelihood that this is the case is that RAC-2 has more ancient mortar adhered to its surface than RAC-1.

Table -5: Drying Shrinkage of Concrete with RCA

| Type of Concrete Mix | Drying Shrinkage (%) |
|---|---|

| | |
|---|---|
| Trial 1 (NAC) | 0.10 |
| Trial 2 (RAC 1) | 0.18 |
| Trial 3 (RAC 2) | 0.24 |

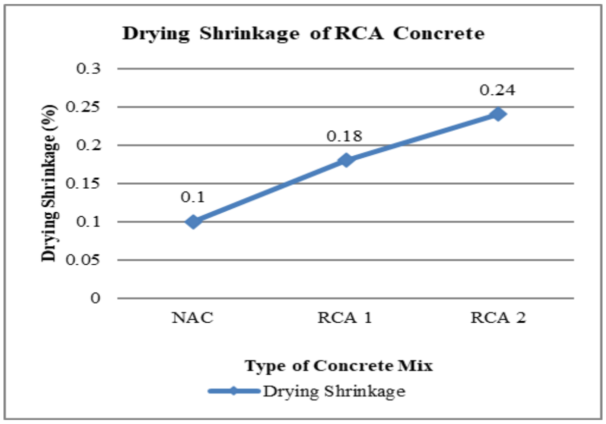


Fig. 2 Drying Shrinkage of Concrete with RCA

*C. Air Content of RCA Concrete:*

The air content of each of the chosen concrete samples is displayed in Table 6.3. It is evident that, in its fresh state, RAC-2 concrete has somewhat higher air content than RAC-1 concrete. The increased amount of old mortar that has stuck to the surface of the RAC-2 aggregates may be the cause of the RAC-2 concrete's higher air content.

Table -6: Air Content of Concrete with RCA

| Type of Concrete Mix | Air Content (%) |
|---|---|
| Trial 1 (NAC) | 13 |
| Trial 2 (RAC 1) | 13 |
| Trial 3 (RAC 2) | 14 |

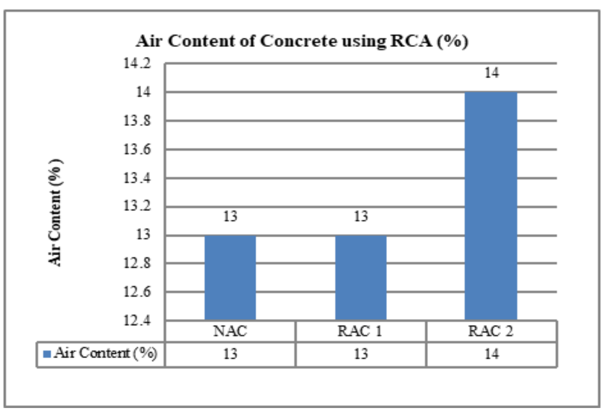


Fig. 3 Air Content of Concrete with RCA

*D. Split Tensile Strength:*

The splitting tensile strength of RAC-1, RAC-2 at both 7 and 28 days are tabulated in Table 7

Table -7: Split Tensile Strength of Concrete with RCA

| Concrete Mix | Split Tensile Strength of RCA Concrete (Mpa) | |
|---|---|---|
| | 7 Days | 28 Days |
| Trial 1 (NAC) | 2.90 | 3.24 |
| Trial 2 (RAC 1) | 2.72 | 2.98 |
| Trial 3 (RAC 2) | 1.95 | 2.65 |

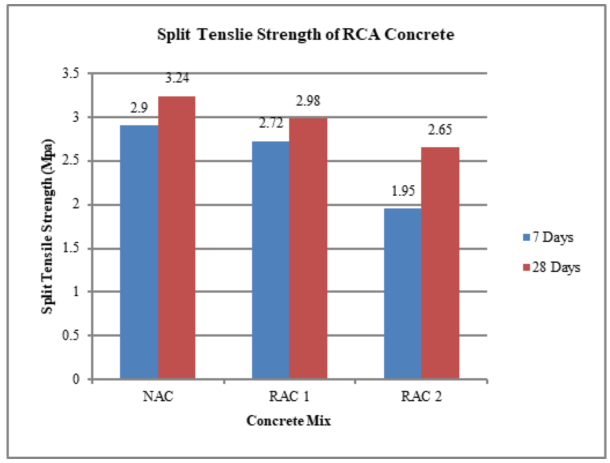


Fig. 4 Variation of Split Tensile Strength

*E. Flexural Strength:*

The flexural strength of RAC-1, RAC-2 at both 7 and 28 days are tabulated in Table 8

Table – 8: Flexural Strength of Concrete with RCA

| Concrete Mix | Flexural Strength of RCA Concrete (Mpa) | |
|---|---|---|
| | 7 Days | 28 Days |
| Trial 1 (NAC) | 6.92 | 8.20 |
| Trial 2 (RAC 1) | 4.95 | 6.65 |
| Trial 3 (RAC 2) | 4.72 | 5.30 |

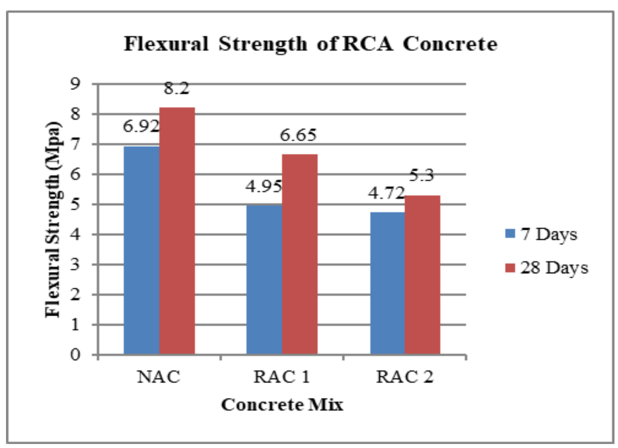


Fig. 5 Variation of Flexural Tensile Strength

*F. Compressive Strength of Concrete using Ureolytic Bacteria:*

The bacterial concrete sample has an exterior surface where white foam-like material is visible, but not in the other two. The mean compressive strength for specimens with different concentration of bacteria at 7 days and 28 days are presented in Table 9.

Table – 9: Compressive Strength of RCA Concrete using Ureolytic Bacteria

| Mix | Bacillus Subtillis | | Bacillus Sphaericus | |
|---|---|---|---|---|
| | 7 Days | 28 Days | 7 Days | 28 Days |
| NAC (0 cells/ml) | 35.47 | 47.17 | 35.47 | 47.27 |
| Control (0 cells/ml) | 31.09 | 40.90 | 31.09 | 40.87 |
| BS-1 ($10^1$cells/ml) | 33.46 | 43.89 | 32.24 | 46.12 |
| BS-2 ($10^3$cells/ml) | 34.99 | 46.15 | 35.94 | 49.98 |
| BS-3 ($10^6$cells/ml) | 36.54 | 49.46 | 41.58 | 55.57 |
| BS-4 ($10^7$ cells/ml) | 35.10 | 47.72 | 37.06 | 51.95 |

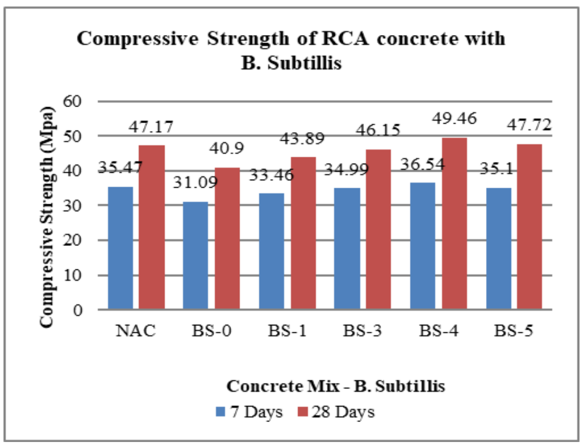


Fig. 6 Compressive Strength of RCA Concrete with Bacillus Subtillis

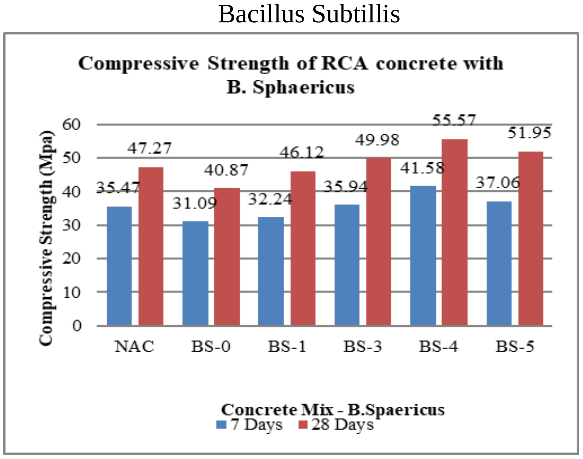


Fig 7 Compressive Strength of RCA Concrete with Bacillus Sphaericus

## V. CONCLUSIONS

1. When compared to RC1, the compressive strength of concrete made with older aggregate is shown to be lower.
2. There was a about 6.5% decrease in compressive strength. The increased amount of adhering porous mortar, which greatly lowers aggregate strength, is likely what caused the loss in compressive strength.
3. At lower weight-to-cement ratios, NCA concrete has a stronger strength than RCA concrete.
4. Nevertheless, there is a reversal of this trend, meaning that after a certain w/c ratio threshold, RCA concrete exhibits stronger compressive strength than NCA concrete.
5. The current study discovered that, in order to contribute to strength, RCA concrete needs a threshold minimum amount of water, which varies based on the parent attached mortar.
6. In contrast to subsequent recycled concrete, the drying shrinkage strain of RC-1 and RC-2 is approximately 1.95 and 2.7 times more than that of NCA concrete, respectively.
7. When RC-2 concrete is compared to RC-1, its splitting tensile strength decreases by 14–29%, while its flexural strength decreases by 6% to 22%.
8. The inclusion of B. subtilis bacteria improves the characteristics of RCA concrete, including its compressive strength, capillary water absorption, and drying shrinkage.
9. At 28 days, it is discovered that, at an ideal cell concentration of $10^6$ cells/ml, the compressive strength of RCA concrete increased by 20% for B. subtilis (B-3A) and 35% for B. sphaericus (B-3B) relative to RCA control mix.
10. Because of the precipitation of calcium carbonate in the pores, both bacillus bacteria are essential for the increase in compressive strength of RCA concrete.

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