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# Assessing Strength and Durability: A Performance Evaluation of Jute Fiber-Reinforced Recycled Aggregate Concrete

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**Abstract:** In recent years, there has been a significant increase in the production of recycled concrete aggregate (RCA) as a result of concrete fabrication and demolition. This has created the need for proper disposal and designated landfill sites for RCA. However, the construction industry has found a valuable solution by utilizing RCA, which not only helps manage landfill space more efficiently but also reduces transportation distances. This approach has contributed to the development of an environmentally conscious construction environment and has further enhanced the production of eco-friendly concrete, often referred to as green concrete. While recycled aggregate concrete (RAC) offers benefits in terms of waste reduction and sustainability, it does present certain drawbacks when compared to natural aggregate concrete (NAC). One of the main concerns is that RAC tends to have increased porosity, which can adversely affect its strength in compression. RCA typically exhibits lower compressive strength than NAC due to the inherent variability in the properties of the recycled aggregates. Therefore, this study targets to examining and establishing a detailed comparative study on the competence of RCA in the fresh concrete addition to jute fiber by replacing the natural aggregate as coarse/fine fraction upto 100%. However, considering all the test results, utilization of RCA with jute fiber proves to be a better option against conventional fresh concrete in building construction sector.

**Key words:** Recycled Aggregate Concrete, Jute Fiber, Mechanical Properties, Porosity, Chloride penetration

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## 1. Introduction

The utilization of recycled concrete aggregate (RCA) in concrete construction has gained significant attention in recent years due to its potential to address environmental concerns and promote sustainable development. The incorporation of RCA not only reduces the demand for natural aggregates but also helps in managing construction and demolition waste. However, the mechanical and durability performance of concrete with recycled aggregates can be influenced by various factors, including the addition of fibers and supplementary cementitious materials.

Ali and Qureshi (2019) investigated the influence of glass fibers on the mechanical and durability performance of concrete with recycled aggregates. Their study focused on understanding the synergistic effects of glass fibers and recycled aggregates on the properties of concrete, such as compressive strength, flexural strength, and resistance to cracking and degradation. The findings highlighted the potential of glass fibers in enhancing the overall performance of concrete with recycled aggregates. In a similar vein, Khan and Ali (2019) explored the improvement in concrete behavior through the incorporation of fly ash, silica fume, and coconut fibers. Their research aimed to enhance the strength and durability properties of concrete using these additives, thereby optimizing the performance of recycled aggregate concrete. Natural fibers, such as jute fibers, have also been investigated for their influence on concrete properties. Islam and Ahmed (2018) studied the impact of jute fibers on the mechanical properties of concrete, focusing on parameters like compressive strength, flexural strength, and toughness. Their research highlighted the potential benefits of jute fibers in enhancing the performance of concrete with recycled aggregates. Apart from natural fibers, synthetic fibers have also been explored. Afroughsabet and Ozbakkaloglu (2015) evaluated the mechanical and durability properties of high-strength concrete containing steel and polypropylene fibers. Their study aimed to assess the impact of fiber reinforcement on the cracking behavior and durability characteristics of recycled aggregate concrete. Furthermore, researchers have investigated the strength and durability evaluation of concrete reinforced with other natural fibers, such as sisal fibers (Sabarish et al., 2017). The study focused on understanding the influence of sisal fibers on properties like compressive strength, flexural strength, and water absorption of concrete with recycled aggregates. In addition to fiber reinforcement, the utilization of supplementary cementitious materials and waste effluents has been explored for improving the properties of recycled aggregate concrete. Raza et al. (2022) conducted an experimental study on the mechanical, durability, and microstructural aspects of coal ash incorporated recycled aggregate concrete. Their research aimed to explore the potential of utilizing waste effluents for sustainable construction.

Overall, the incorporation of fibers and supplementary cementitious materials, along with the use of waste effluents, provides promising avenues for enhancing the mechanical and durability performance of recycled aggregate concrete. This literature review highlights the various studies conducted in this field and serves as a foundation for further research and development in sustainable concrete construction.

## 2. Experimental Programme

### 2.1Materials

**Table 1** shows the property of 53 grade of cement purchased from the local suppliers and tested as per the BIS in Concrete technology laboratory which is located at GMR Institute of Technology, Rajam. The property of fine aggregate (FA), recycled fine aggregate (RFA), coarse aggregate(CA) and recycled coarse aggregate (RCA) test has done in the above mentioned laboratory which is summarized in **Table 2**.The below mentioned **Table 3** property of Jute fiber (JF) data has been collected from the manager of GMR Jute mill and the same material I have collected from the Jute mill and utilized for preparing the Jute fiber reinforced concrete.

***Table 1 Property of 53 grade of Cement***

| **Property** | **Value** |
|---|---|
| Specific gravity | 3.12 |
| Fineness of Cement | 8% |
| Normal Consistency | 32% |
| Initial Setting time | 50min |
| Final Setting time | 8hr.20min |

***Table 2 Property of Aggregate***

| Property | FA | RFA | CA | RCA |
|---|---|---|---|---|
| Specific Gravity | 2.61 | 2.02 | 2.629 | 2.02 |
| Fineness Modulus | 2.99 | | | |
| Water Absorption | 1% | 16.05% | 1% | 16.05% |

***Table 3 Property of Jute fiber***

| Property | Jute fiber |
|---|---|
| Fiber length | 0.8-6 mm |
| Fiber diameter | 5-25 μm |
| Tensile strength | 393-773 Mpa |
| Youngs modulus | 13-26.5 Gpa |
| Moisture content | 1.10% |
| Density | 1.46 g/cc |

**2.2 Mix proportions**

**Table 4** provided information presents various concrete mixes with different compositions and replacements of materials. The mixes are labeled from Mix1 to Mix18, each with specific variations in the ingredients.Mix1 represents the conventional mix, serving as the reference point for comparison. Mix2 introduces JF with varying percentages such as 0.5% to 2.5% with an increment of 0.5%. Mix3 to Mix6 involve the replacement of RCA with CA at different percentages (30%, 50%, 70%, and 100% respectively).Mix7 to Mix10 combine the replacement of RCA with CA along with the addition of JF at different percentages. Mix11 to Mix14 replace RFA with FA at various percentages (30%, 50%, 70%, and 100% respectively).Mix15 to Mix18 incorporate the replacement of RFA with FA and the addition of JF at different percentages. The JF percentages range from 0% to 2.5% of the weight of the concrete. This extensive range of mix variations allows for the study and evaluation of the effects of different materials and their proportions on the properties and performance of concrete. It enables researchers and engineers to assess the impact of these modifications on strength, durability, workability, and other essential u of the concrete mixes.

***Table 4 Details of Mix Propertions***

| Mix | Description |
|---|---|
| Mix1 | Conventional mix |
| Mix2 | Conventional mix with JF with different percentage |
| Mix3 | 30% replacement of RCA with CA |
| Mix4 | 50% replacement of RCA with CA |
| Mix5 | 70% replacement of RCA with CA |
| Mix6 | 100% replacement of RCA with CA |
| Mix7 | 30% replacement of RCA with CA and addition of JF percentage |
| Mix8 | 50% replacement of RCA with CA and addition of JF percentage |
| Mix9 | 70% replacement of RCA with CA and addition of JF percentage |
| Mix10 | 100% replacement of RCA with CA and addition of JF percentage |
| Mix11 | 30% replacement of RFA with FA |
| Mix12 | 50% replacement of RFA with FA |
| Mix13 | 70% replacement of RFA with FA |
| Mix14 | 100% replacement of RFA with FA |
| Mix15 | 30% replacement of RFA with FA and addition of JF percentage |
| Mix16 | 50% replacement of RFA with FA and addition of JF percentage |
| Mix17 | 70% replacement of RFA with FA and addition of JF percentage |
| Mix18 | 100% replacement of RFA with FA and addition of JF percentage |

### 2.3Preparation of sample

For determining the compressive strength 150 × 150 ×150 mm concrete cube casted for all the different types of mix in the laboratory and the test has been conducted in concrete technology laboratory after the completion of 28 days of curing. The compressive strength has performed by using 2000 kN ACTM. For the purpose of split tensile strength 150 mm diameter and 300 mm height cylinder prepared as per the requirement and testing has to be done by using the above mentioned instrument device. For obtaining the experimental flexural strength 100 mm × 100 mm × 500 mm size prism casted in the concrete laboratory and testing has to be conducted in Universal Testing machine of 1000 kN capacity.

## 3.Results

### 3.1 Mechanical performance

#### 3.1.1 Compressive strength

The provided Fig.1 represents the compressive strength (in MPa) of different mixtures containing JF and RCA at various percentages. The percentage error analysis provides valuable insights into the effects of varying percentages of JF and RCA on the compressive strength of concrete mixtures. The results indicate that the replacement of natural coarse aggregate with RCA leads to a gradual decrease in compressive strength as the RCA percentage increases. The percentage errors range from approximately -3.53% to -2.76% for each 30% increment in RCA content. This highlights the detrimental impact of RCA on the compressive strength of the mixtures. On the other hand, the inclusion of JF exhibits a relatively minor effect on compressive strength. As the JF percentage increases, there is a slight decrease in compressive strength compared to the reference mixture. The percentage errors range from approximately -1.21% to -0.23% for each 0.5% increment in JF content. Although the decrease in compressive strength is small, it is worth considering when optimizing the JF percentage in concrete mixtures. The observed trends in the percentage error analysis suggest that the use of RCA negatively affects the compressive strength more significantly than the inclusion of JF. However, it is important to note that the variations in compressive strength among the different mixtures are relatively small. This indicates that the compressive strength of the mixtures containing JF and RCA can still meet the desired requirements for many applications. It is crucial to approach the findings of this analysis with caution, as they are based on the provided data and certain assumptions. To determine the optimum percentages of JF and RCA, further testing, experimentation, and consideration of other factors such as durability, workability, and cost are necessary. Additionally, specific project requirements and performance criteria should be taken into account to ensure the suitability of JF and RCA in concrete mixtures.

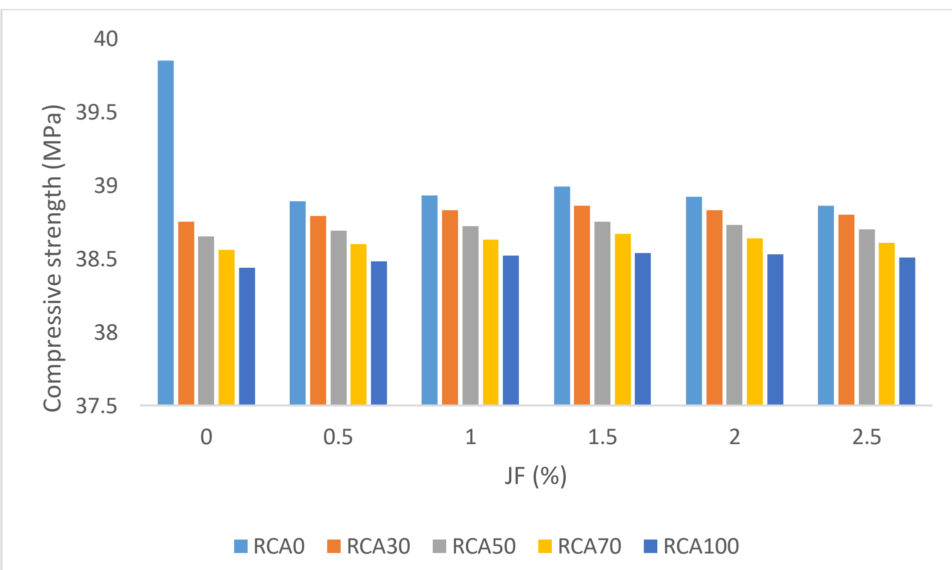


Fig.1 compressive strength (in MPa) of different mixtures containing jute fiber (JF) and recycled coarse aggregate (RCA) at various percentages

The provided Fig.2 represents the compressive strength (in MPa) of different mixtures containing JF and RFA at various percentages. The percentage error analysis reveals interesting observations regarding the effect of JF and RFA on the compressive strength of concrete mixtures. Firstly, focusing on the impact of

RFA percentage, we notice a clear trend of decreasing compressive strength as the RFA content increases. The percentage errors consistently become more negative with higher RFA percentages, indicating a decline in strength compared to the reference mixture (JF-RFA0). This trend suggests that the inclusion of recycled fine aggregate leads to a reduction in compressive strength. The highest percentage error of -3.47% is observed for JF-RFA100, where the entire fine aggregate is replaced with recycled material. This finding underscores the potential limitations of using higher proportions of RFA, as the inferior properties of recycled fine aggregate can negatively affect the overall strength of the concrete. On the other hand, the influence of JF percentage appears to be relatively minor compared to RFA variations. The percentage errors for different JF percentages remain within a narrower range of -1.99% to -3.50%. This indicates that the addition of Jute Fiber has a relatively smaller impact on the compressive strength of the concrete mixtures. It is worth noting that despite the slight reduction in strength, incorporating JF offers other benefits such as improved crack resistance and enhanced durability. Therefore, the use of JF can still be considered advantageous in concrete mixtures, as long as the desired strength requirements are met. Overall, the percentage error analysis provides valuable insights into the performance of the JF-RFA concrete mixtures. While the percentage errors are generally negative, suggesting a reduction in compressive strength, it is important to consider other factors beyond strength alone. Parameters such as workability, durability, and cost should also be taken into account when evaluating the overall performance of the mixtures. The selection of the optimum JF and RFA percentages should be based on a comprehensive assessment of project requirements, performance criteria, and the desired balance between material properties and sustainability considerations.

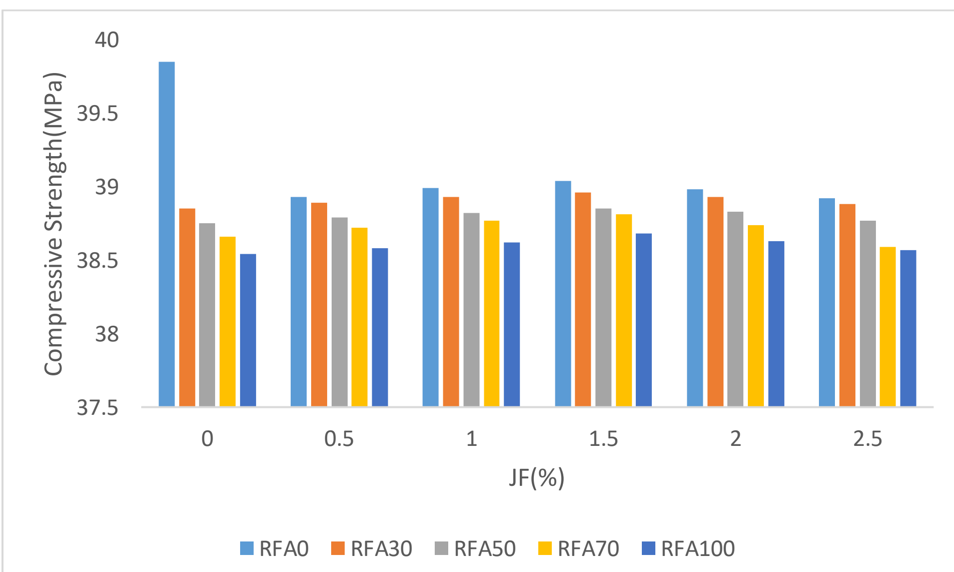


Fig.2 compressive strength (in MPa) of different mixtures containing jute fiber (JF) and recycled fine aggregate (RFA) at various percentages

### 3.1.2 Split tensile and flexural strength

Fig.3, Fig.4 represents different combinations of JF percentages and RFA or RCA levels along with their corresponding TS and FS values. Let's discuss the trends observed in the data. Looking at the Tensile Strength values, it can be observed that as the Jute Fiber percentage remains constant at 1.5%, the TS values also remain relatively constant. Across different RFA or RCA levels, ranging from RFA0 to RFA100, the TS values vary within a narrow range of 3.42 to 3.44 MPa. This indicates that the inclusion of Jute Fiber has minimal influence on the tensile strength of the composite material when compared to changes in the RFA level. On the other hand, analyzing the Flexural Strength values, a similar pattern emerges. As the Jute Fiber percentage remains constant, the FS values also remain relatively stable. Across the various RFA or RCA levels, the FS values range from 4.35 to 4.37 MPa, displaying a small variation similar to the Tensile Strength. The consistent behavior in both TS and FS, irrespective of the Jute Fiber percentage, suggests that the RFA or RCA level plays a more significant role in determining the mechanical properties of the composite material. The inclusion of JF, within the tested range of 1.5%, does not seem to have a substantial impact on the material's strength. However, it is worth noting that the data provided only represents a limited number of JF and RFA or RCA combinations. To draw more comprehensive conclusions, further experimentation and analysis would be necessary. Additional data points involving different JF percentages and RFA or RCA levels could provide a clearer understanding of the relationship between these variables and the resulting mechanical properties.

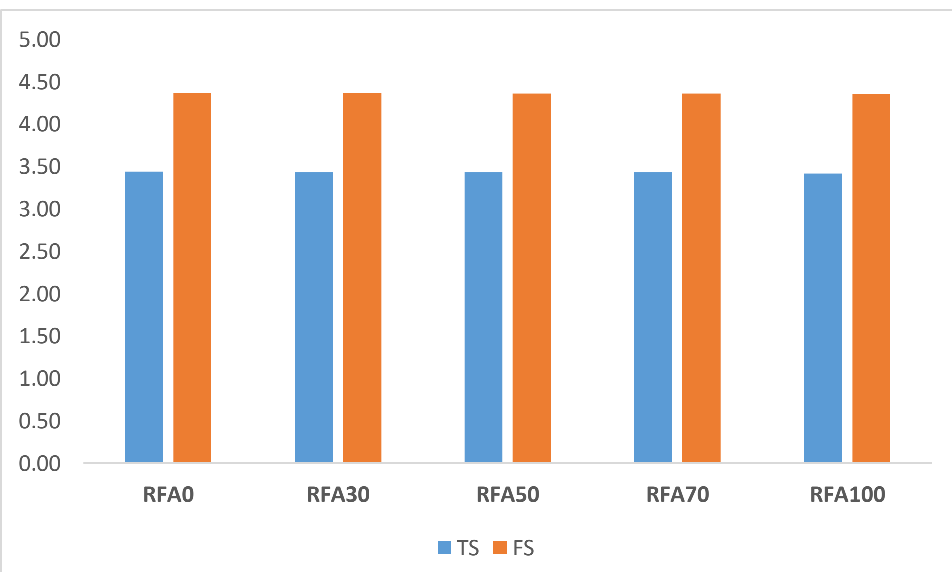


Fig.3 Split and Flexural strength (in MPa) of different mixtures containing JF and recycled RFA at various percentages

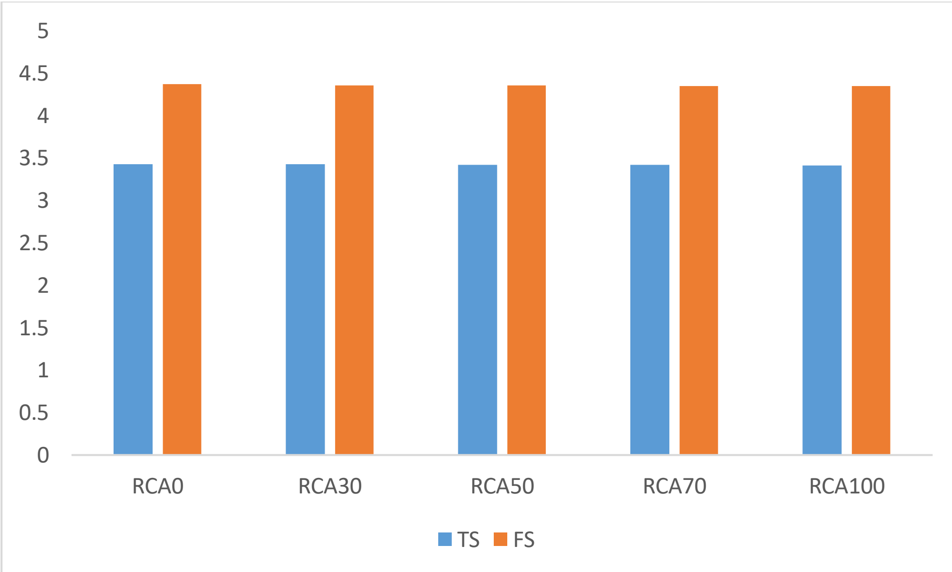


Fig.4 Split and Flexural strength (in MPa) of different mixtures containing JF and recycled RCA at various percentages

### 3.2 Durability performance

#### 3.2.1 Porosity

The comparison of porosity percentages between RFA (Recycled Fine Aggregate) and RCA (Recycled Coarse Aggregate) in Figure 5 provides valuable insights into the distinctions between these two types of recycled aggregates. The figure reveals consistent higher porosity percentages in RFA compared to RCA across all conditions. The errors range from 1.3 to 1.7, indicating a substantial disparity in porosity between the two aggregate types. These discrepancies can have significant implications for the performance and behavior of concrete or other applications utilizing these aggregates. One plausible explanation for the higher porosity of RFA lies in the particle size distribution. Coarse aggregates, with their larger particle sizes, tend to have higher packing density, resulting in reduced porosity. Conversely, fine aggregates like RFA typically consist of smaller particles, leading to increased porosity. The disparity in particle size distribution between RFA and RCA can contribute to the observed variations in porosity. Another factor influencing porosity is the quality of the recycled aggregates. The recycling process may introduce impurities or contaminants, which can impact the porosity and overall performance of the recycled aggregates. Variations in production methods or the sources of the original materials used for recycling can contribute to differences in porosity percentages between RFA and RCA. Additionally, compaction plays a vital role in determining aggregate porosity. The compaction process influences the void space within the aggregates, and inconsistent compaction between RFA and RCA could result in divergent porosity percentages. It is important to note that porosity significantly affects the properties and durability of concrete, as higher porosity generally leads to increased water absorption and reduced strength.

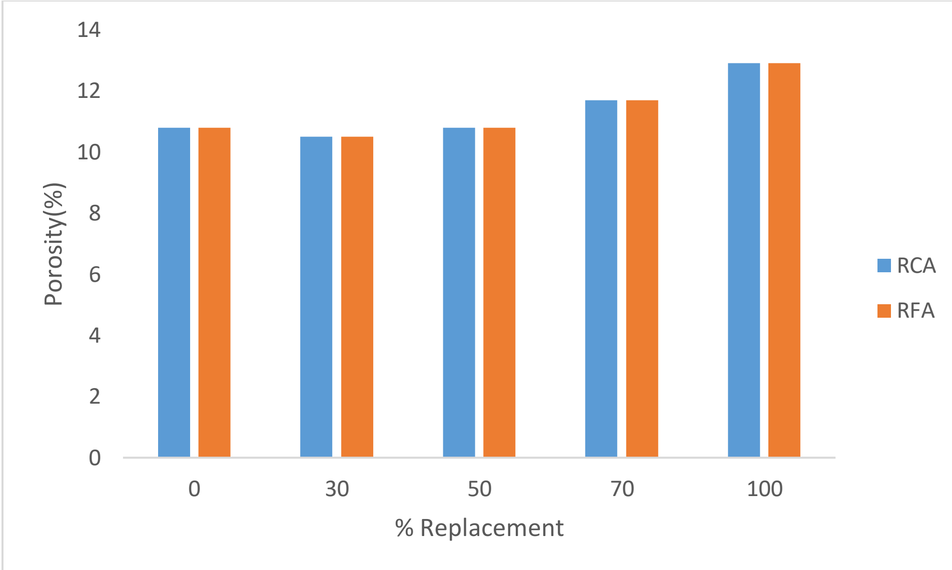


**Fig.5 porosity (%) of containing jute fiber (JF) and recycled fine aggregate (RFA) and recycled coarse aggregate (RCA) at optimum percentages**

### 3.2.2 Chloride Penetration

The Fig.6 above showcases the absolute differences in chloride penetration between RFA and RCA aggregates for each condition. These values indicate the deviation or error in chloride penetration between the two types of recycled aggregates. Upon analyzing the error table, it becomes apparent that there are variations in chloride penetration between RFA and RCA aggregates. For the RFA0 and RCA0 conditions, there is a minimal difference of only 0.01 mm. However, as the conditions progress, the differences become more pronounced, with errors ranging from 0.96 mm to 1.66 mm. The discrepancies in chloride penetration between RFA and RCA aggregates could be attributed to various factors. One factor is the particle size distribution. Coarse aggregates generally have larger particles, resulting in reduced porosity and potentially lower chloride penetration compared to fine aggregates. Additionally, the quality of the recycled aggregates, the presence of impurities, and variations in production processes can all influence chloride penetration behavior. These errors in chloride penetration highlight the importance of selecting the appropriate type of recycled aggregate based on the desired performance characteristics. In applications where chloride penetration resistance is crucial, such as in marine environments or structures exposed to de-icing salts, choosing the aggregate with lower chloride penetration values, as evident in this case with RCA, may be more desirable. It is worth noting that additional testing and analysis are necessary to comprehensively understand the factors contributing to the observed errors. Conducting further investigations into the particle size distribution, material quality, and production methods for both RFA and RCA will provide valuable insights into optimizing the selection and use of recycled aggregates in chloride-rich environments.

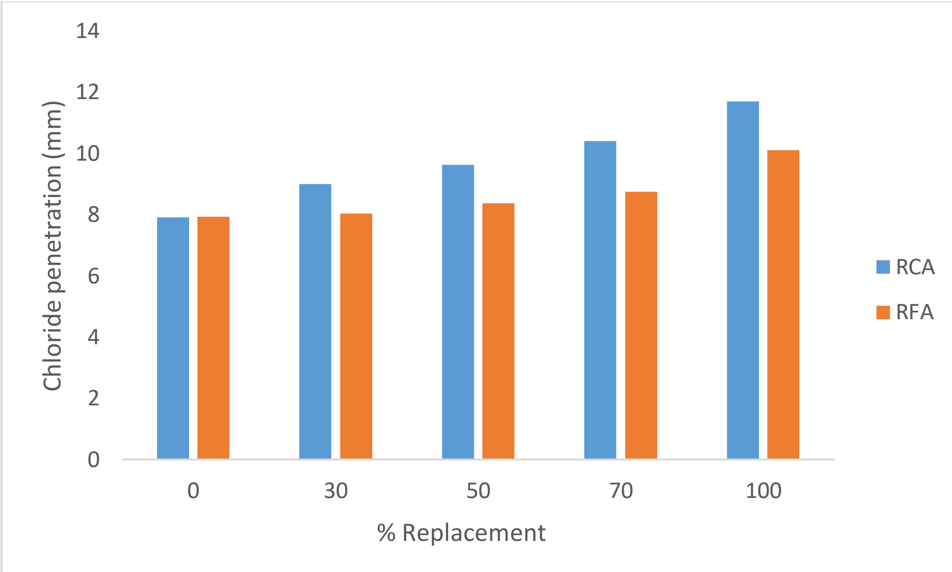


Fig.6 chloride penetration (mm) of containing jute fiber (JF) and recycled fine aggregate (RFA) and recycled coarse aggregate (RCA) at optimum percentages

**4. Conclusion**

In the present study, concrete mixes were prepared using 30, 50, 70 and 100% RCA by the replacement of NCA and reinforcement with different volume fraction of JF (0.5, 1, 1.5 and 2.5 %). Similarly, NFA was replaced by RFA with varied volume fraction of JF in the concrete mixes. The compressive strength has done for all the sample and based upon the optimum results the split tensile strength and flexural strength were evaluated. In the same way two types of durability performance viz. porosity and chloride penetration evaluation has done as per the optimum results.

(1)The observed trends in the percentage error analysis suggest that the use of RCA negatively affects the compressive strength more significantly than the inclusion of JF. The percentage error analysis highlights the importance of carefully selecting the proportions of JF and RFA in concrete mixtures. By considering the trade-off between strength, sustainability, and other material properties, it is possible to design mixtures that fulfill project requirements while incorporating sustainable materials.

(2) It can be inferred that the TS and FS of the composite material are relatively unaffected by variations in the Jute Fiber percentage. The RFA level appears to have a more prominent influence on the mechanical properties, although further investigation would be required to establish a comprehensive understanding of these relationships.

(3) The porosity percentages of RFA and RCA sheds light on the differences between these recycled aggregates. The higher porosity observed in RFA compared to RCA highlights the importance of careful material selection and production processes in recycling aggregates. Understanding and minimizing these discrepancies are essential for optimizing the performance and durability of concrete and other applications

utilizing recycled aggregates. Continued research and development efforts in this area will contribute to more sustainable and reliable construction practices in the future.

(4)The chloride penetration values of RFA and RCA aggregates reveals variations in chloride penetration behavior. These differences underscore the need for careful consideration of the aggregate type in applications where chloride resistance is crucial. Further research and understanding of the factors influencing chloride penetration behavior in recycled aggregates are essential for informed decision-making in construction practices.

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