Innovative Use of Momordica Angustisepala Fibers for improved strength of Recycled Concrete

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Abstract— **The consistent demands for natural aggregate by the construction industry is on the increase and consequently cost of construction is affected. The increase in demand for natural resources for construction and the continuous depletion of such resources could create environmental and sustainability issues. In the quest for provision of affordable housing around the world, the adoption of waste concrete material for construction and in particular as a replacement of aggregates in concrete is becoming an option. Past researches showed that the strengths of concrete produced with waste concrete are lower than that produced with natural aggregates. This paper examines the potential of improving strength of concrete produced from recycled waste concrete as aggregate materials with different proportions of fiber added to the mix. Concrete cubes of dimension 150 mm x 150 mm x 150 mm and cylinders were cast at the Structures Laboratory of the Department of Civil Engineering, Covenant University, Ota, Nigeria. The cubes were prepared by replacing the coarse aggregate of normal concrete mix with 0, 20, 50, 70, and 100% of waste concrete aggregate. Momordica Angustisepala fiber (local sponge) was added in proportion of 0.25%, 0.5% 0.75%, and 1% by mass of aggregates. Tests conducted on both fresh and hardened concrete include: slump test on fresh concrete, compressive strength of the concrete cubes and split tensile strength of concrete cylinders. Statistical methods were used to analyze the test results. The test results indicated an appreciable increase in strength of fiber reinforced waste aggregate concrete. Test results show that RCA of up to 50% can be used to obtain a good concrete mix while Momordica Angustisepala fiber content of up to 0.5% can be used to improve compressive and tensile strength of concrete.**

Index Terms— **Recycled Concrete, Aggregates, Momordica Angustisepala Fibers, Compressive Strength, Split Tensile Strength.**

I. INTRODUCTION

'According to Henry et al. [1]', the construction industry represents one of the most dynamic and complex industrial sector in every nation of the world as increases in construction activities is very common. This means more and more natural resources are being depleted and more construction wastes are also being generated. Construction waste is a growing problem in many countries because of its increased burden on landfill sites operation and the consequent surface and underground pollution that accompany it. According to [2], over 15 metric tonnes of solid wastes are generated annually from construction industries in Nigeria, which include wasted sand, gravel, bitumen, bricks and masonry concrete. Globally, portions of such waste is being recycled and utilized in building materials. Therefore, concrete recycling is very important for sustainable development in current [3]. Currently in major cities within Nigeria like Lagos, there are limited land space available for development. This implies that for future development within the major city metropolis, some existing structures must be demolished and the resulting waste are cart away to dump sites since the issue of managing construction waste materials is relatively a new practice in the construction industry. According to [4], the generation rate of municipal solid wastes in urban areas such as Ota metropolis, Ogun State, Nigeria, have increased at a disturbing rate over the years while lack of efficient and modern technology for the waste management turns it to a big problem for the society. When added to the increasing generation of demolition waste, the total level of waste will only increase the source of soil, water and air pollution. This will go forth to aggravate the problems of low environmental awareness of the construction wastes generated in the country and the urban waste disposal management issues in general.

Currently, the choice of construction materials are based on strength, cost of material, ease of access and erection, aesthetics, sustainability and environmental considerations [5]. Generally, it has been established that the cost of materials account for a great percentage of the total cost of construction projects. A better management of construction materials through the adoption of construction waste can translate to cost control which means wealth generation for the construction industry. Therefore, a more intelligent reutilization of waste construction materials on site should be adopted [6]. One of such environmentally friendly practices adopted as a control in most part of the world is the recycling of construction and demolition waste generated by the construction industry. Some materials can be recycled directly into the same product for re-use. Others can be reconstituted into other usable products. The work of [7] have revealed that different substitute materials are currently utilized for concrete production. According to [8], the increase in prices of building materials, human development and knowledge advancement makes the concept of recycling and reusing to become both a necessity and a challenge to the society. In the quest for provision of affordable housing around the world, the adoption of waste concrete material for construction and in particular as a replacement of aggregates in concrete is becoming an option even as past researches have noted reduced strengths of recycled aggregate concrete.

On the other hand, cement concrete made of Portland cement, fine and coarse aggregates, water and most often with admixtures is the major construction material for all types of civil engineering works. Today, the rate at which concrete is used is much higher than it was 40 years ago [9]. However, the increase in human developments has led to researching into possible recycling and using recycled concrete materials as a new source of aggregates in the construction industry. Recycled aggregate concrete is the concrete produced from old crushed and recycled concretes, as a partial or total replacement of natural aggregates. Such aggregates can be coarse or fine. Recycled concrete is a viable source of aggregate and has been adequately used in granular sub-bases, soil-cement, and in new concrete. The future benefits and drawbacks of using recycled aggregate in concrete have been extensively studied by many researchers, [10-18]. Before recycled concrete aggregate can be ready for reuse, crushing and screening are required to produce aggregates within the limits of mixing gradation. From economic point of view, Recycling aggregate concrete is an attractive option. Past researches showed that the strengths of concrete produced with waste concrete are lower than that produced with natural aggregates. According to [19], the compressive strength decreased with increase in water – cement (w/c) ratio and is directly proportional to strength of the blended aggregate. Also, [20] stated that the extent to which the properties of concrete are affected by the use of recycled aggregate depends on the water absorption, crushing value and soundness of the recycled aggregates.

In recent years, many researches have been working on how to improve concrete strength through the use of fiber. Fiber reinforced concrete can be defined as a composite material made with Portland cement, aggregates, water, discrete dispersion of chopped short fibers [21]. This enhances the post cracking ductility and allow for higher load resistance as the mechanical properties of the fiber play significant role when cracks occur. Various types of fibers have been adopted to improve the strength of concrete. Ede and Ige [22] found that the optimal percentage of polypropylene fiber for improved compressive and flexural strengths lies within 0.25% and 0.5%. The properties of coconut fiber for increasing concrete strength, toughness, durability and ductility have been found by various researchers [23-26]. Few works have taken place on the application of Momordica Angustisepala Fiber for the improvement of concrete strength. The Momordica Angustisepala fiber predominantly grows in the forest zone of West Africa from Cote d'Ivoire, Ghana, Benin, and Nigeria to Cameroon [27]. It belongs to the family "Cucubitaceae" and is scientifically referred to as "Momordica Angustisepala Harms". According to Atuanya in [28], Momordica. Angustisepala fiber has shown potential to be a significant material for any composite material production due to its remarkable properties. Tensile tests results obtained by Atuanya [28] showed that the fiber has a tensile modulus of 2-4.4 x 103 MPa and a tensile strength of 35–57.93Mpa. Salau in [29] found that the addition of 0.25% of Momordica Angustisepala fiber in plain concrete improved the compressive strength up to 4.37%.

This study examines the potential of improving strength of concrete produced from recycled waste concrete as aggregate materials with different proportions of Momordica Angustisepala fiber added to the mix. This research represents a novel application of this natural fiber on recycled concrete. It aims at examining the influence of Momordica Angustisepala fiber in the compressive and split tensile strength of concrete, produced from conventional concrete constituents and partially replaced by recycled concrete aggregate (RCA).

II. MATERIALS AND METHODS

Materials Preparation

The constituent materials adopted for concrete production in this research are ordinary Portland cement of grade 32.5, 4.75 mm sieve-passing River sand and granite aggregate of sizes of between 10mm and 20mm. The recycled concrete (RCA) used as aggregate was sourced from construction waste concrete meant for the dump sites. The RCA was prepared by breaking the waste concrete into sizes of the granite aggregates, then impurities and unwanted particles were removed. Potable water was used for both mixing and curing of the cubes and cylinders. The Momordica Angustisepala fiber was added in varying percentage to test the effect on compressive and tensile strength.

Samples of the fiber is shown in Figure 1.

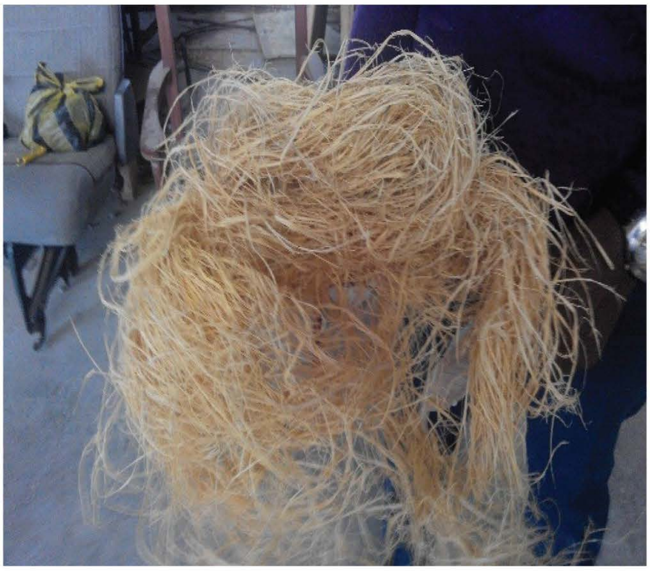

Fig. 1. Momordica Angustisepala fiber

Methods

Five categories of concrete cubes and cylinders were produced using both conventional concrete constituents and recycled waste concrete. Each category is based on the percentage RCA (0 - 100%) and fiber content (0 – 1%). The mix design ratios of cement: sand: coarse aggregate used for all the five categories is 1:2:4. That is, the concrete were all prepared by replacing the coarse aggregate of normal concrete mix of 1:2:4 with 0, 20, 50, 70, and 100% of waste concrete aggregate (RCA). The Momordica Angustisepala fiber was added in proportion of 0.25%, 0.5% 0.75%, and 1% by mass of aggregates. The water – cement ratio (w/c) is 0.6. Two Hundred and twenty five (225) number cubes and cylinders were cast for the various laboratory tests that were carried out. The materials were batched by weight and thoroughly mixed to ensure even distribution of the constituents within the mixtures. The concrete cubes of dimension $150x150x150mm^3$ and cylinders of diameter 150mm and height of 300mm produced for each category were cured for 7, 14 and 28 days, by immersion in water. Tests were carried out in line with the British Standards [30].

Slump test was carried out to determine the workability and consistency of fresh concrete mix. The slump cone of height 300mm, base diameter of 200mm and top diameter of 100mm and a tamping rod was employed to carry out this test.

The Compressive strength of each Momordica Angustisepala fiber reinforced concrete cubes at curing ages of 7, 14 and 28 days was determined. Average of three compressive strength results, for each curing period, category and mix proportion, was determined. The compressive strength of the cubes was determined in compliance with British standards [30] using YES-2000 digital display compression machine.

The split tensile strength of each Momordica Angustisepala fiber reinforced concrete cylinders at curing ages of 7, 14 and 28 days was determined. Test main objective is to determine the tensile strength of concrete mix for each category. Average of three split tensile strength results, for each curing period, category and mix proportion, was determined. The split tensile strength of the cylinders was determined in compliance with British standards [30] using YES-2000 digital display compression machine.

III. RESULTS AND DISCUSSION

Slump Test

The slump test results for the fresh concrete for 0 – 100% RCA with 0.25% to 1% Momordica Angustisepala fiber added showed trends of low workability. The slump results decreases as the percentage fiber contents are increased from 0 – 1% which indicates that the workability of the fresh RCA concrete vary inversely with the percentage fiber content of the mixtures.

Compressive strength

The compressive strength results for cubes, after 7, 14 and 28 days of curing and for 0 – 100% RCA with 0% to 1% Momordica Angustisepala fiber are presented in bar charts of Figures 2 to 6 while strength variations for 0% RCA and 100% RCA for varying percentages of Momordica Angustisepala fiber contents were shown in Figures 7 and 8.

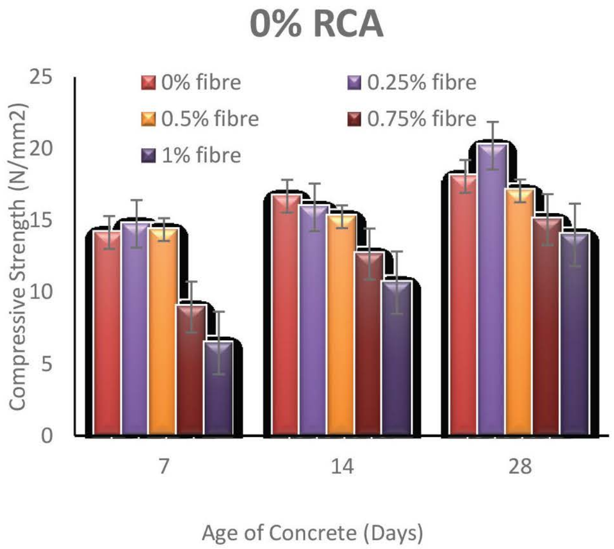

Fig. 2. Variation of 7, 14, 28-days compressive strength of Concrete with 0% waste concrete and 0 – 1% fiber added

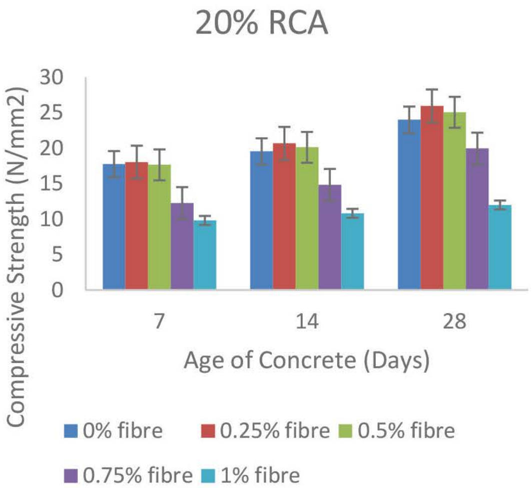

Fig. 3. Variation of 7, 14, 28-days compressive strength of Concrete with 20% waste concrete and 0 – 1% fiber added

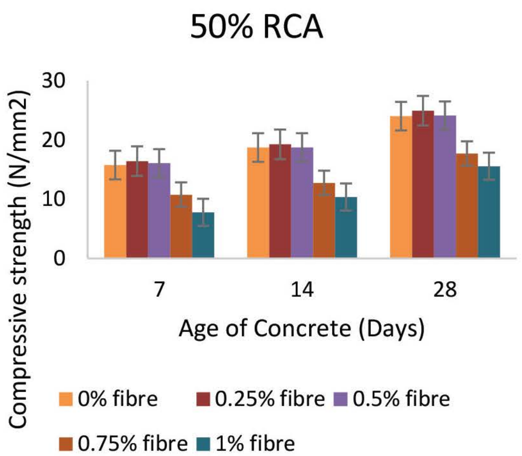

Fig. 4. Variation of 7, 14, 28-days compressive strength of Concrete with 50% waste concrete and 0 – 1% fiber added

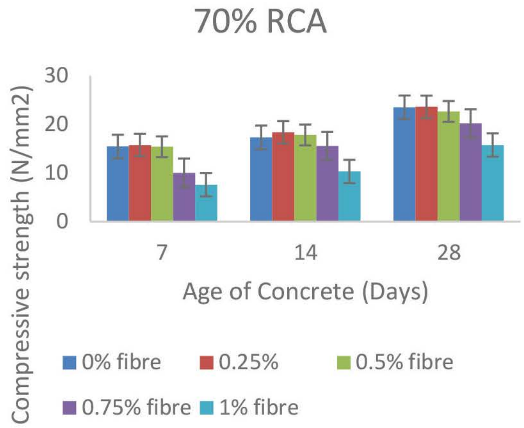

Fig. 5. Variation of 7, 14, 28-days compressive strength of Concrete with 70% waste concrete and 0 – 1% fiber added

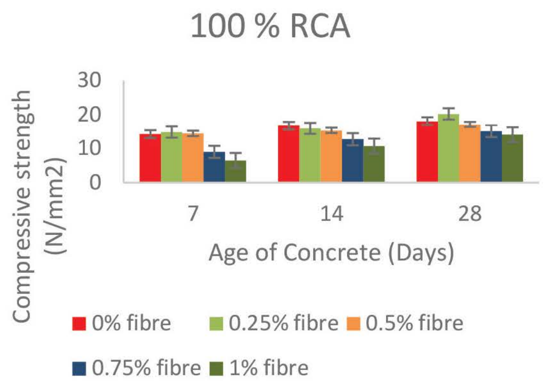

Fig. 6. Variation of 7, 14, 28-days compressive strength of Concrete with 100% waste concrete and 0 – 1% fiber added

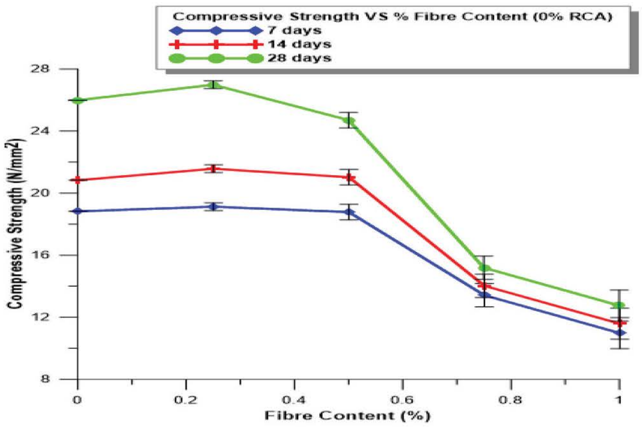

Fig. 7. Variation of compressive strength of Concrete with 0 – 1% fiber for 0% RCA at curing ages

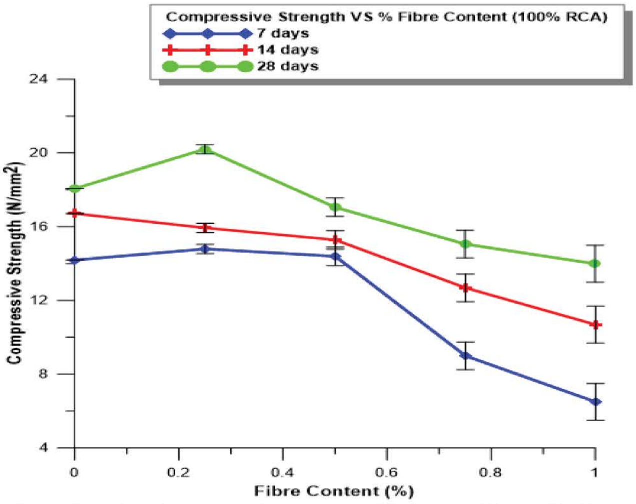

Fig. 8. Variation of compressive strength of Concrete with 0 – 1% fiber for 100% RCA at curing ages

For the effect of fiber on recycled aggregate concret (RCA), except for 14 days of 0% RCA and of 70% RCA respectively, in which 0% fiber content produce the highest compressive strength and the 28 days of 70% RCA in which 0% fiber and 0.25% had maximum equal strength, the 0.25% fiber content generally gave the maximum compressive strength gain in all the other test performed. The performance of 0.5% fiber content was averagely equal or above the 0% fiber contents while 0.75% and 1% fiber content performed abismally bad as all their compressive strengths were far below the strength for 0% fiber content.

As regards the the effect of RCA on the compressive strength of concrete, 25% RCA, 50% RCA and 75% RCA all gave good compressive strength around the bench mark of 25N/mm^2 for 0% to 50% fiber content. 100% RCA gave a very poor result. A consistent decrease in the compressive strength was observed as the Momordica Angustisepala fiber content was increased from 0.5% to 1%.

Tensile Strength

The split tensile strength results for the cylinders, after 7, 14 and 28 days of curing and for 0 – 100% RCA with 0% to 1% Momordica Angustisepala fiber are presented in bar charts of Figures 9 to 13.

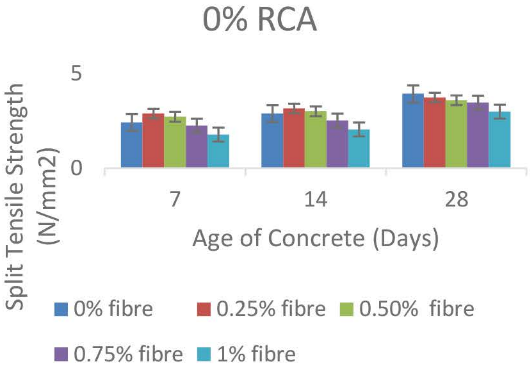

Fig. 9. Variation of 7, 14, 28-days split tensile strength of Concrete with 0% waste concrete and 0 – 1% fiber added

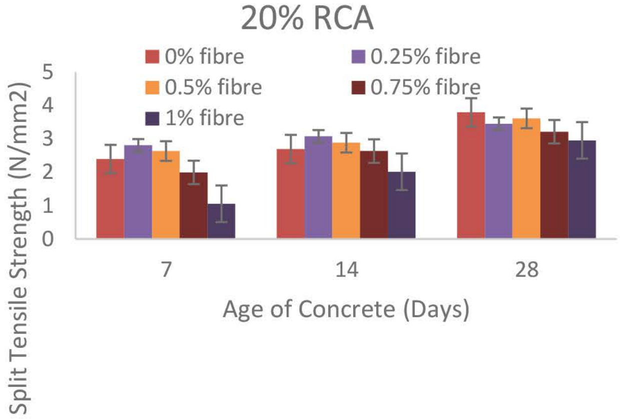

Fig. 10. Variation of 7, 14, 28-days split tensile strength of Concrete with 20% waste concrete and 0 – 1% fiber added

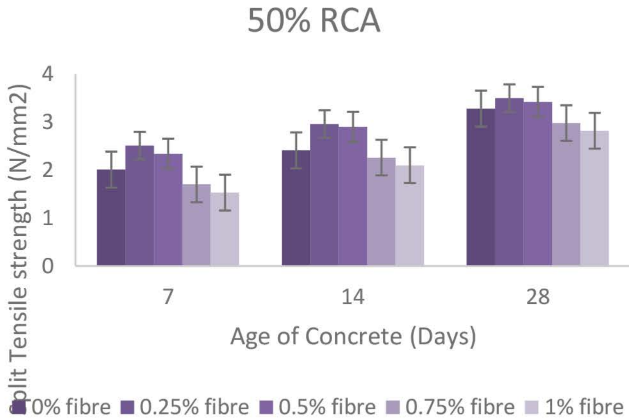

Fig. 11. Variation of 7, 14, 28-days split tensile strength of Concrete with 50% waste concrete and 0 – 1% fiber added

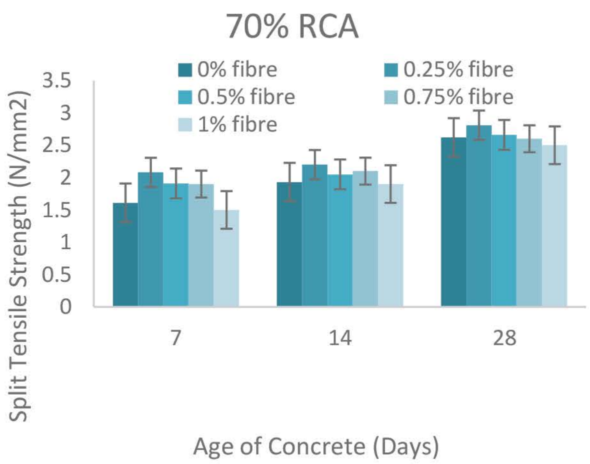

Fig. 12. Variation of 7, 14, 28-days split tensile strength of Concrete with 70% waste concrete and 0 – 1% fiber added

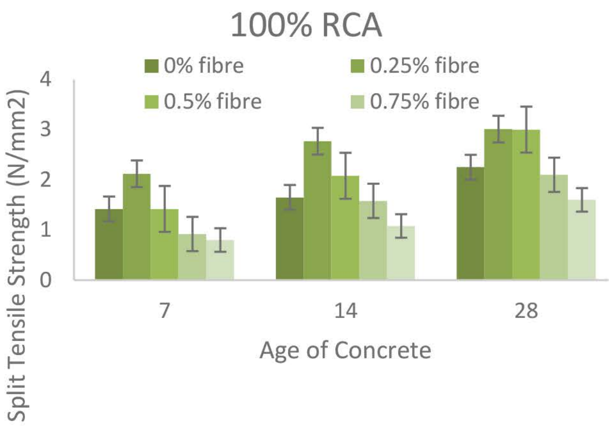

Fig. 13. Variation of 7, 14, 28-days split tensile strength of Concrete with 100% waste concrete and 0 – 1% fiber added

For the split tensile tests, 0.25% and 0.50% Momordica Angustisepala fiber contents gave higher strengths for 7 and 14 days of 0% RCA and 20% RCA while the 0% Momordica Angustisepala fiber content gave the highest tensile strength at 28 days for these percentage of RCA. For 50%, 75% and 100 RCA, 0.25% and 0.5% Momordica Angustisepala fiber contents gave tensile strengths greater than that of control sample for all the curing days.

IV. Conclusion

This research reinforced the facts that the compressive and tensile strength of concrete produced from recycled waste concrete are lower as the percentage of RCA increases while the decrease in strength was very pronounced as the RCA contents exceed 50%. Between 0 and 50 percent of RCA, a good concrete can still be obtained with a slite variation of other constituent materials. The optimal Momordica Angustisepala fiber content for improved compressive and tensile strength was 0.25% while the optimal RCA contents for improved compression and tensile strength was 20%.

From these test results, it can be concluded that RCA of up to 50% can be used to obtain a good concrete mix while Momordica Angustisepala fiber content of up to 0.5% can be used to improve compressive and tensile strength of concrete. However, further studies will be required to better understand the process of using Momordica Angustisepala fiber for improved strengths of concrete needed for sustainable national development.

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