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Flexural strength of recycled aggregate concrete reinforced with nylon fibers

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K E Y W O R D S

Sustainable Development

Recycled Aggregate Concrete

Demolished Waste

Nylon-Fibers

Workability of Fibrous Concrete

Flexural Strength

A B S T R A C T

The effect of binary blending of recycled aggregates and nylon fibers on the workability and flexural strength of concrete has been investigated in this work. An equal dosage of recycled aggregates from demolished wastes and conventional aggregates was used with 0.5 water cement ratio in preparing a mix of 1:2:4. Nylon fibers were used from 0% to 2% with an increment of 0.25% by weight of cement to reinforce the concrete. The slump cone test was determined for all nine batches of the concrete. Workability was observed to reduce with an increase in the content of nylon fibers. Flexural strength was evaluated by testing three prism specimens of 150mm x 150mm x 500mm size in each batch. A comparison of test results with control concrete (0% nylon fibers) and recycled aggregate concrete (with 50% recycled aggregates and without fibers) showed that nylon fibers helped in overcoming the loss of flexural strength due to the addition of recycled aggregates. The optimum dosage was recorded as equal to 1.5% with an increase in strength equal to 19.13% and 52.45% in comparison to conventional and recycled aggregate concrete.

1. Introduction

Construction remained a need of mankind since the early days. With time systematic approach to the job turned into the construction industry. The industry underwent several changes with respect to material, design philosophy, construction approach, and management skills. With regard to the material, concrete is now the most popular material for construction than others. Even it is believed that it is one of the widely used materials after water. Since the advent of concrete construction of desired shapes and sizes has commonly been seen in the industry.

The pace of development in every country has increased but the recent boom in construction particularly the vertically tall buildings is increasing. This on the other hand consumes concrete at mass scale. Thus, the quarrying of aggregates and production of cement has also increased. This in turn is dangerous to the environment and to early health of peoples due to carbon dioxide emission. The space required for the construction of tall buildings and associated infrastructure require space which is almost unavailable in city centers around the world. Therefore, those infrastructure which completed the service life, deteriorated buildings, and short height buildings are demolished to create space for vertically tall buildings. The process yields massive quantum of the demolished waste. A part of the waste is used as filling material whereas the rest is used to dump in the dumping areas, but already unavailability of land, has made dumping of waste another problem. Disposing off this waste to far places by transportation creates the additional overburden on the project. Letting the waste dumped around or at outskirts of a city not only creates aesthetic issue but also pose serious problem to the environment and agricultural land in case of agricultural country like Pakistan. Therefore, a solution of it, is to make use of it in new construction. Numerous constituents of this waste have been attempted by scholars in new construction work. The demolished concrete has also been attempted in making of new concrete after recycling as coarse and fine aggregates. Using the waste as coarse aggregates is much feasible as coarse aggregates consumes large portion of the body of concrete. The processing of the waste into recycled aggregates is an additional burden on the project also it greatly influences the properties of the ultimate product by using it. A variety of recycling methods for construction and demolition wastes (CDW) have been discovered and are in a well-developed stage [1], [2] in the last two decades. A number of countries have developed regulations for processing and using the waste in new concrete. In a few countries a few full-scale short-height buildings and a few roads have also been developed using recycled aggregates and are termed green structures. This shows the possible use of the waste in new concrete. However, careful considerations must be made before using the waste as RCA. Researchers in their research, have found lower specific gravity and higher water absorption capacity when compared to the natural aggregates due to the attached dry mortar with it [3], [4]. They also added that properties of concrete made with RCA are largely dependent on the superiority of the primary concrete. Therefore, the strength of the concrete using recycled aggregates is lower as compared to conventional concrete.

The strength of concrete is being an important property to confirm the safety and serviceability of a structure through its service life cannot be compromised. Thus, efforts have been made to improve the strength of recycled aggregate concrete using various materials and techniques. The use of the fibers is one of the factors among many others. Various types of the fibers i.e., natural, synthetic, and steel fibers have successfully been dosage in conventional concrete. Also, the fibers have been used in recycled aggregate concrete to attempt the development in its strength properties but still, the scatter of the results is evident in the literature. Beams are the structural members that have to face transverse loading and remain under the action of flexure. Thus, these members should have enough flexural strength to survive under the applied loading during service life. Hence, the investigation and improvement of the parameters for recycled aggregates are also important. Therefore, this research proposes the use of nylon fibers to find out its effect on the flexural strength of recycled aggregate concrete.

2. Literature review

The review of the literature relevant to the proposed topic not only reveals what work has been done in the areas but also provides information about hurdles and strategies for further work. Thus, this section summarizes the available literature relevant to the proposed research.

The usage of demolished waste by way of coarse aggregates in preparation of fresh concrete is not new but is an active area of research among scholars as it is an eco-friendly material and needs of the day. It not only lessens the waste management burden but also proves as an alternative to conventional ingredients of the concrete matrix. Kalra and Mahmood [1] and Memon [2] in separate articles studied the practice of different aggregates from waste as coarse aggregates in new concrete. The authors highlighted the processing methods and hurdles associated with it and summarized the different properties of aggregates researched by previous scholars. Mushiruddin and Singh [4] investigated water absorption, capillary and drying shrinkage along with compressive strength of recycled aggregate concrete but used silica fume and fly ash as additives to improve the targeted properties. The authors observed an increase in all the above-mentioned properties. Specially 21% increase in compressive strength was recorded in comparison to concrete without additives. Therefore, the authors resolved that careful use of the additives not only improves the properties of concrete but also helps in the reduction of CO_2 due to less quarrying of aggregates and less generation of cement.

Reddy and Swaroop [5] in their research program used demolishing waste as fine and coarse aggregates from 0 to 50% with an increment of 5%. The effect of specific gravity, water absorption and particle size distribution on the strength of the concrete was also examined. Test results proved that dosage up to 35% gives better results but beyond it fails to show any improvement. On the contrary Vinay [6] concluded his research with 40% of RCA as optimum but he used fly ash also in his experimental program. The test results showed that 10% fly ash gives better results; thus may be treated as an optimum dosage of fly ash. A good increase from conventional concrete at the RCA dosage of 40% and fly ash dosage of 10% was observed in the research work. The author further argues that beyond above mentioned dosages i.e., at 50% dosage of RCA strength was not even half of the already recorded values.

Ahad and Alvi [7] used a 50% dosage of recycled aggregates to prepare recycled aggregate concrete to study its strength properties. This research work prepared the samples and cured them for 7-, 14- and 28-days. For 28-day cured specimens, authors observed a 9% and 6% reduction in compressive and flexural strength. Both reduction values are observed less than 10% shows that 50% is a reasonably good dosage to develop recycled aggregate concrete. In another attempt, Memon and Bhatti [8] observed a 12% decrease in the flexural strength of reinforced recycled aggregate concrete beams cast with a 50% dosage of recycled aggregates. The above-mentioned values were recorded as optimum among various other dosages of RCA up to 80%. Oad et. al in two separate research works regarding flexural stress-strain behavior of reinforced recycled aggregate concrete beams made by using plain [9] and rich mix [10] observed 5.5% and 12% reduction in flexural strength for plain and rich mix concrete respectively.

The flexural strength of the reinforced recycled aggregate concrete made by using an equal dosage of conventional and recycled aggregates and exposed to different duration of fire has been studied by Buller et. al. In their separate research works the authors exposed the reinforced recycled aggregate concrete beams to fire at 1000°C for 6 hours [11], 12 hours [12], 18 hours [13], and 24 hours [14]. After the exposure to fire, the specimens (beams) were left to cool in open air and then allowed to test for flexural behavior. The test results showed 8%, 48%, 22% and 32% reduction in flexural strength of the beam for a 6-, 12-, 18- and 24-hours fired beam respectively. Although the residual flexural strength after fire except for a 6-hour fire duration was less it gives a clear idea of the residual strength and effect of fire which in turn to help in deciding proper remedial measures for retrofitting and rehabilitation.

The usage of the different types of fibers in conventional concrete and their effect on various fresh and hardened properties of concrete are well understood. These fibers include synthetic, steel, coconut coir, nylon, etc. While using steel fibers Islam et. al. [15] observed 2.5% as optimum, as at this dosage of fibers authors observed a 17% and 30% rise in the compressive and flexural-strengths of the concrete. Likewise, the use of the fibers showed good improvement in post-cracking behavior, energy absorption and ductility of the concrete.

To study the flexural strength of recycled fine aggregate concrete Nam et. al. [16] used polyvinyl alcohol and nylon fibers in the concrete. Fibers were used in dosages of 0.05% and 0.1%. Test results showed the authors good efficiency of concrete against drying shrinkage cracks than mechanical properties of the concrete. The flexural strength of the concrete was observed slightly better than the recycled aggregate concrete without fibers. Lee [17] in his research used 100% recycled aggregates and nylon fibers in the dosages of 0.6 and 1.2 kg/m^3 and found the permeability and mechanical properties of recycled aggregate concrete. The conventional and SEM tests were done on the samples. In the results, the authors observed lower performance of the concrete due to the attachment of the old mortar with the recycled- aggregates. And also added that a 1.2 kg/m^3 dosage of the fibers produces the better outcomes in evaluation to conventional concrete.

Nylon fibers were also used by Biswas et. al. [18] in conventional concrete to study its compressive and tensile strengths. The test program used cubes and cylinders cast with 0, 0.1%, 0.2% and 0.3% dosage of nylon fibers. Test results showed a considerable increase in both strength properties at a dosage of 0.2%. Hence 0.2% was recommended as the optimum level of the nylon fibers concerning compressive and tensile strength. Steel fibers have also been attempted in recycled aggregate concrete with fly ash, metakaolin and silica fume geopolymer recycled aggregate concrete. In this connection, Xu et. al. [19] used various dosages of fibers to study the microstructural behavior and properties of the concrete strength. Analogous to others the authors observed a decrease in slump as the dosage of the fibers increased. However, the presence of fibers in concrete improved the compressive, flexural and tensile strengths by 16%, 64%, and 61% respectively. The authors also observed that the presence of silica fume restrains the development of cracks in the concrete. Steel fibers were also used by Venugopal [20] for making recycled aggregate concrete. Author dosages, 0, 50% and 100% of recycled aggregates along with (0, 0.5%, 1.0% and 1.5%) of steel fibers to develop concrete samples of M20 grade concrete. The results of 7 and 28-day cured specimens presented a good increase in compressive, tensile, and flexural strength of concrete even at 100% replacement dose of conventional- aggregates with recycled aggregates from demolished- concrete.

Steel fibers with PVA were also used by Kin and Kim [21] along with fly ash, recycled fine aggregates and recycled coarse aggregates to develop high toughness cement composite concrete. The term relates to concrete with conventional ingredients and fibers. Test results revealed a good reduction in the shrinkage strain of concrete and a good increase in the compressive and flexural strengths of the concrete. A combination of nylon and steel fibers with a constant dosage (0.75%) of steel fibers was used by Kohila and Vijayalakshmi [22] to develop M30-grade concrete. Nylon fibers were incorporated in the quantity of 1%, 2% and 3%. The outcomes for compressive and flexural strengths showed 2% as the optimum dosage of the nylon fibers.

Nylon fibers were also used in the development of self-compacting concrete by Ahmad et. al. [23] in the dosages of 0.5% to 2% with an increment of 0.5% by weight of cement. The test results showed a reduction in the passing and filling ability of concrete whereas the remarkable increase in segregation and bleeding resistance of the concrete was recorded. From the used dosages, the authors observed a 1.5% dose of the fibers as optimum with respect to tests conducted in the research. Improvement of workability besides the early age of concrete strength was attempted by Shoaib et. al. [24] using basalt fibers. The fibers of 20mm and 43mm were attempted with the replacement of 100% natural coarse aggregates with recycled coarse aggregates obtained from demolishing concrete waste. A decrease in workability and a slight rise in compressive strength were witnessed for both lengths of the fibers but the performance of 43mm fibers was recorded better compared to 20mm length fibers.

Nylon fibers were also attempted in the rehabilitation of the deteriorated structures by Hossain et. al. [31]. Deteriorated columns were selected for the purpose and applied by nylon-fiber reinforced mortar. Remarkable achievement in the performance of repaired columns was noticed by the authors.

The above arguments of the relevant available state of the art reveal clearly that quality time and efforts have been spared by the several researchers in all the areas of the world to use recycled aggregates in development of the green concrete. They found different properties of the aggregates and different properties of concrete adding them in fresh and hardened states have also been studied/tested. They also used various additives and different types of fibers in concrete and then tested for the enhancement of various properties of the recycled concrete. In the literature, very little work has been found on the use of nylon fibers for improving the flexural strength. Hence, more work is needed in this field to reach a certain level of confidence on use of the materials. Thus, this research work planned the use of both nearby accessible demolishing wastes and nylon fibers in the development of concrete to find the consequence of nylon fibers on flexural strength. It will not only help in understanding the effect on flexural strength of recycled aggregates concrete with nylon fibers, enrich the literature on the topic, and provides guidelines to future researchers but also lower to some extent the burden of waste management.

3. Materials and Testing

In the subsequent subsection, specifics of materials used to perform the laboratory investigations for the proposed subject are given.

3.1 Cement

Ordinary Portland cement (Pakland cement) was used in the present study. The physical observations of the material are related to grey colour, smooth and no lumps. To check the fineness of cement #100 sieve was used by ASTM C184-94 [27]. After arithmetic, the fineness was found equal to 95.3%. The Initial setting time, final setting time and consistency of cement were evaluated using Vicat needle apparatus and were found equal to 63 min, 392 min, and 31% respectively. The experimental parameters of cement agreed well with ASTM-C150 standards [28].

Fig. 1. Photograph of a Cement Bag

Fig. 2. Fine and Coarse Aggregates

3.2 Fine Aggregates

Fine aggregates were obtained from approved quarries of the government and was used in preparing concrete. The pictorial view of the material is shown in Fig. 2. The sieve analysis of hill sand was performed as per ASTM C33/C33M-18 standards [29]. Fig. 3 shows percentages passing on various sieves. The process revealed the fineness modulus of the material identical to 2.71. The range achieved drops in the range of medium sand and decides well with the relevant requirements of the standards.

3.3 Coarse Aggregates

Conventional aggregates used in this study were also attained from accepted sources of the government. The maximum size of the aggregates observed is equal to 25mm (Fig. 2) ranging from 4.75mm-25mm. After washing and drying the aggregates, sieve analysis was performed as per ASTM C33/C33M-18 standards [29]. The proportion of passing on various sieves is exposed in Fig. 4. From sieve analysis results fineness modulus was computed equal to 5.75.

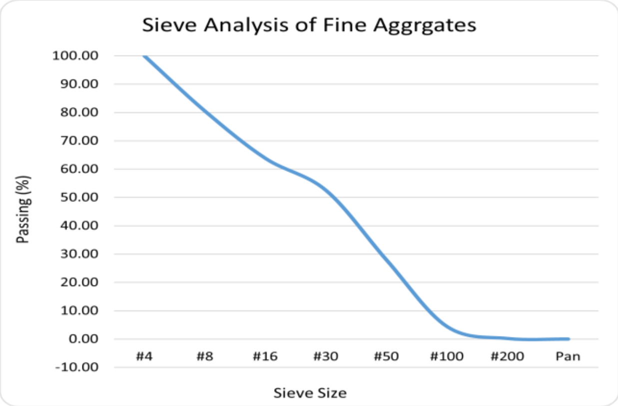

Fig. 3. Sieve Analysis of Hill Sand

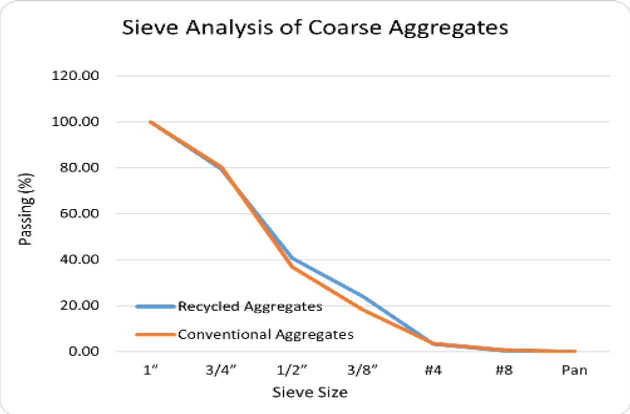

Fig. 4. Sieve Analysis of Coarse Aggregates

3.4 Water

For washing and mixing of concrete ingredients, potable water is required. Also, the same is used for curing the concrete. Therefore, the water obtained from the water supply line was tested. The pH of the water was equal to 6.8, EC was found equal to 1210 µS/cm and TDS was equal to 672 mg/L.

The recorded values show that the water used was potable water and fit for concrete.

3.5 Recycled Aggregates

The recycled aggregates incorporated in this research were brought from Nawabshah, Sindh, Pakistan (Fig. 5) a demolished school building situated in the Mehran colony. The required size of coarse aggregates (maximum 25mm size) was obtained by hammering large blocks from collected old concrete. The impurities and the cracked particles were manually sorted from recycled aggregates and tracked by washing and drying in the research laboratory. There after sieve analysis of the material was completed in an analogous fashion to conventional coarse aggregates. The arithmetic calculations for the fineness modulus revealed it equal to 5.65. The percentage passing of the material on various sieves is shown in Fig. 4 along with conventional coarse aggregates for the comparison. Both recycled and conventional coarse aggregates were used in equal proportions. The selected amount is based on the recommendations of references [5, 7, 26].

Fig. 5. Demolished Waste and Recycled Aggregates

Fig. 6. Nylon Fibers

3.6 Basic Properties of Coarse Aggregates

The basic properties of both conventional and recycled aggregates listed in Table 1 have been investigated using the standard procedure of the test specified by relevant ASTM standards. The obtained results are listed in Table 1 along with the percentage difference with conventional aggregates. It may be observed that except for specific gravity, all the properties showed higher values from 32% to 228 %. These increased property values are due to the age, exposure of the concrete during service life, and old mortar attached to the aggregates. It all makes the recycled aggregates weaker than the conventional aggregates. This drawback affected the hardened properties of concrete using these aggregates. Thus, additional material or procedure is required to counter it. To this end, this research work used nylon fibers.

Table 1

Basic properties of coarse aggregates

Properties	NCA	RCA	Deviation (%)
Water absorption (%)	1.71	3.81	122.81
Specific gravity	2.55	2.34	-8.24
Abrasion (%)	16.10	29.10	80.75
Soundness (%)	4.49	5.92	31.85
Impact value (%)	16.35	32.7	100.00

Crushing value (%)	15.2	30.1	98.03
LOI (%)	0.7	2.3	228.57

3.7 Nylon Fibers

1 mm in diameter and 25 mm length of the nylon fibers were used in this study. Therefore, the aspect ratio of the fibers was equal to 25. The tensile strength of the fibers was evaluated and seen same as 415 MPa. These fibers were used from 0% to 2% with an increment of 0.25% by weight of cement. Thus, nine different dosages hence the concrete mixes were used. Among these mixes, the mix with 0% fibers was treated by means of a control mix to equate the results of planned concrete. Also, a blend with a 50% dosage of recycled aggregates but without nylon fibers was prepared to check and relate the effect of recycled aggregates. Hence altogether ten concrete mixes were designed for this research work. Fig. 6 shows the image of the fibers.

3.8 *Workability of Concrete*

For the dosages of nylon fibers explained earlier, nine concrete mixes were prepared using normal mix (1:2:4 ratio) and 0.5 water cement ratio. The ratio of the mix was selected based on the fact that it is commonly and broadly used in the construction industry. To check the effect of nylon fibers on concrete workability, a slump cone test was done for each mix in accordance with ASTM-C143 [30]. The ingredients were weighted by weight method followed by mixing them in a concrete mixer till a uniform paste was prepared. For all the mixes, the same process was repeated. Slump cone for each mix was filled in turn in three layers with twenty-five strokes of taming rod to each layer. Finally top surface was leveled then cone was carefully lifted. The reduction in height was measured in a standard way. Fig. 7 shows the pictorial view of the test of a mix. Table 2 gives the details of the slump results of entire mixes.

Fig. 7. Performing Slump Test

Fig. 8. Prism Specimens

Table 2

Slump values of all mixes

Reading #	Mix	Nylon fibers	Slump
1	CM	0.0	85
2	RAC	0.0	81
3	B-1	0.25	78
4	B-2	0.50	73
5	B-3	0.75	66
6	B-4	1.0	64
7	B-5	1.25	52
8	B-6	1.50	50
9	B-7	1.75	41
10	B-8	2.0	27

3.9 *Specimen Preparation and Curing*

For evaluation of the flexural strength, three prisms of 150mm x 150mm x 500mm size were cast in each batch using the same mix and water-cement ratio as explained earlier. The prism moulds were prepared by oiling the inner surface. Concrete mix was prepared in same fashion as for slump cone test. Moulds were filled in three layers and compacted by a needle vibrator. After one day, specimens were de moulded and then permitted to air-dry for 24 hours in the laboratory (Fig. 8). Then all the samples were allowed to cure for 28 days by entirely dipping in the potable water.

Fig. 9. Specimen Testing Procedure

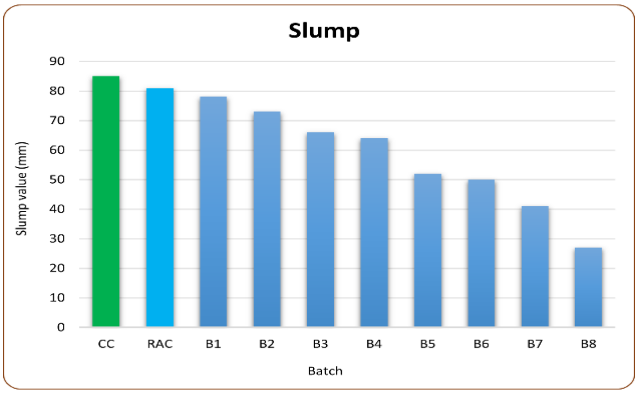

Fig. 10. Comparison of Slump Values

3.10 Flexural Strength

After the accomplishment of the curing age, samples were taken out of the water. The surface was wiped off with a clean cloth followed by allowing them to air dry for 24 hours in the laboratory. Each specimen in turn was then tested in universal testing-machine (UTM) under a two point load in agreement with ASTM C42/C42M-22 [31] standard. Maximum sustained load and deflection were recorded. The peak load was then used to compute flexural strength using the standard formula ($3PL/2bd^2$) provided by the code. The obtained results are tabulated in Table 3. A few specimens during testing are shown in Fig. 9.

Table 3

Flexural strength

Batch	Nylon Fiber (%)	RCA (%)	Flexure Strength (MPa)			Average FS (MPa)
			Sp. 1	Sp. 2	Sp. 3	
CC	0	0	4.50	4.65	4.58	4.58
RAC	0	50	3.60	3.68	3.45	3.58
B1	0.25	50	4.58	4.43	4.65	4.55
B2	0.50	50	4.80	5.03	4.58	4.80
B3	0.75	50	5.03	5.10	5.10	5.08
B4	1.00	50	5.25	5.18	5.10	5.18
B5	1.25	50	5.25	5.33	5.40	5.33
B6	1.50	50	5.48	5.40	5.48	5.45
B7	1.75	50	4.95	5.10	4.65	4.90
B8	2.00	50	4.65	4.58	5.33	4.85

4. Results and Discussion

Slump test results tabulated previously are plotted as a bar graph in Fig. 10 to compare the results with natural aggregate concrete and recycled aggregate concrete. It may be observed that the induction of recycled aggregates resulted in the loss of 4.7% slump and was aggregated due to the addition of nylon fibers. At the dosage of 1.5% of nylon fibers slump is reduced by 41%. At the same dosage of nylon fibers, the loss of slump was 38% in comparison to recycled aggregate concrete. This shows that due to interlocking developed in concrete by nylon fibers flow of it is affected. This must be considered in the plan of concrete either by adjusting of water-cement ratio or by using a plasticizer to maintain the workability of the concrete.

The flexural strength of individual specimens in each batch is plotted in Fig. 11 for visualization. The average of three specimens in each batch was computed and is shown in Fig. 12. It is observed that the induction of recycled aggregates badly affected the flexural strength with 78.14% residual strength. The strength was observed to improve due to the induction of the nylon fibers. The lowest dose of the fibers merely compensated for the loss of flexural strength due to recycled aggregates. But with an increase in the significance of the fibers flexural strength increased even beyond the flexural strength of conventional concrete up to B6 (1.5% fibers). Beyond this dosage, the flexural strength again started declining. It is anticipated that up to 1.5% dosage of the fibers, concrete ingredients were better interconnected with each other but beyond this dosage, the content of fibers increased to the extent that binder force between ingredients reduced than required thus the flexural strength dropped. However, up to the maximum dosage of the fibers used in this study, the flexural strength was observed higher than the flexural strength of conventional concrete.

Fig. 13 and Fig. 14 show the percentage deviation of flexural strength of proposed concrete versus control concrete and recycled aggregate concrete respectively. When compared to control concrete the percentage increase in flexural strength of nylon fiber reinforced concrete is 19.13% beyond which strength started reducing but even at the highest dose of the nylon fibers used in this work flexural strength was observed 6% higher than that of the conventional concrete. At optimum dosage the increase in flexural strength was 13.74% higher than the same reported by Munadrah et. al. [32] and 6.13% and 7.73% higher than Hanif et. al. [33] and Bheel et. al. [34] respectively. This shows the better performance of the fibers in concrete beams tested under two-point loading. The two- point loading predicts the strength more accurately than a single-point loading.

When compared with recycled aggregate concrete, all the batches of nylon fiber reinforced concrete observed an increase in flexural strength with a maximum of 52.45% higher strength than recycled aggregate concrete without nylon fibers. This demonstrates the effective practice of nylon fibers in recycled aggregates concrete which not only provides better interlocking of the concrete aggregates but also compensates the loss of strength due to the recycled aggregates.

At the ultimate load, failure of the specimens was observed flexural failure about the center of the beam from extreme compression to extreme tension fibers. A few of the specimens at failure load are shown in Fig. 15. The bonding of the nylon fibers with concrete ingredients shows effective performance and helps in attaining flexural behavior instead of shear failure which is dominant in plain concrete.

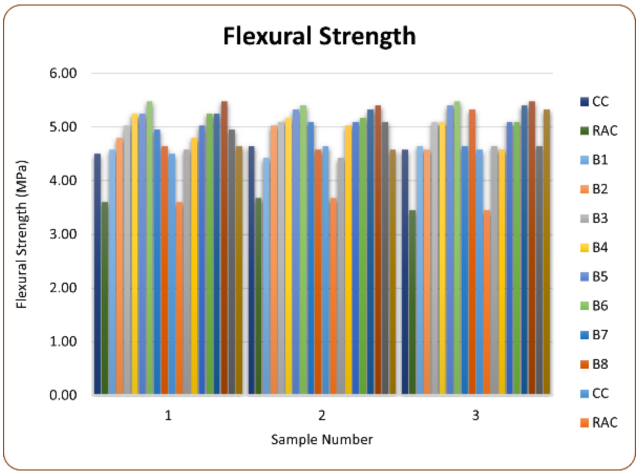

Fig. 11. Flexural Strength of All Specimens

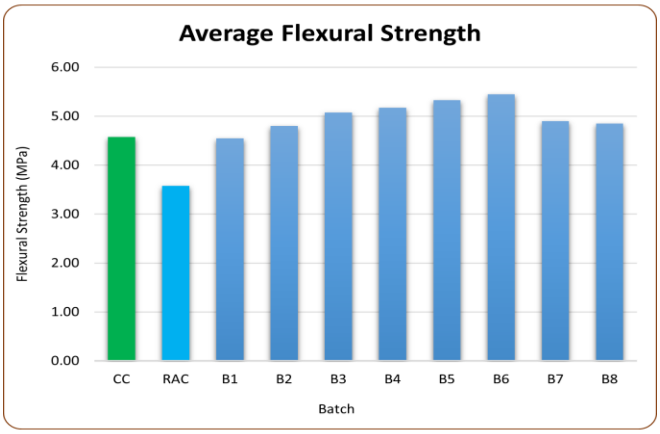

Fig. 12. Average Flexural Strength

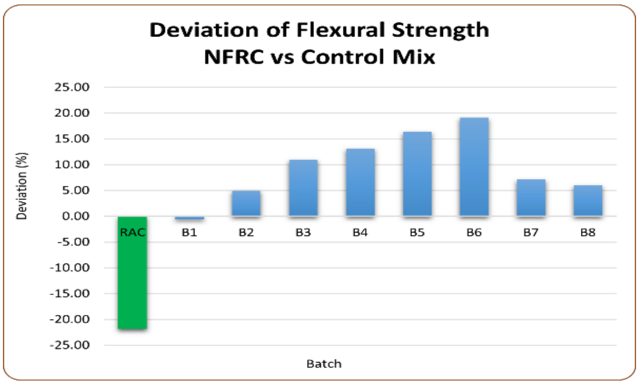

Fig. 13. Deviation of Flexural Strength Vs Control Mix

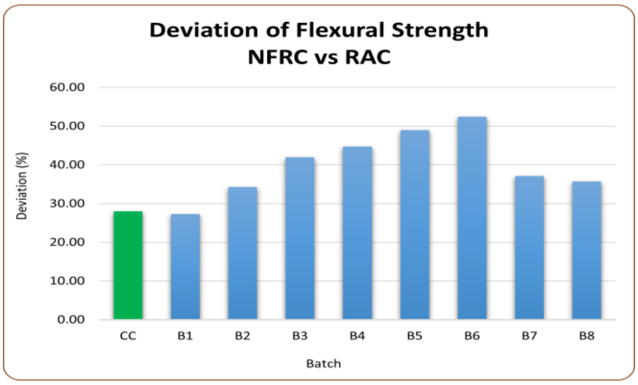

Fig. 14. Change of Flexural Strength Vs Recycled Aggregates Concrete

Fig. 15. Specimens At Ultimate Loa

5. Conclusion

This research paper presents the consequences of the combined use of recycled aggregates and nylon fibers on the workability and flexural strength of recycled aggregate concrete. On the analysis of the results, followings are the conclusions.

1. Recycled aggregates reduced the flexural strength of concrete by 21.86%.
2. The slump of the concrete was reduced owing to the addition of nylon fibers.
3. The addition of nylon fibers in recycled aggregate concrete compensated for loss of strength even at low dosages.
4. With the increase in nylon fibers content, flexural strength was observed to increase with the maximum of up to 1.5%.
5. Further than 1.5% of nylon fibers flexural strength lessened nevertheless was observed more than both recycled and conventional concrete.
6. Failure of specimens was observed flexural about the center of the specimens instead of shear failure which is dominant in plain concrete.
7. Nylon fibers provide better interlocking of the concrete fibers.

8. With 1.5% dosage of nylon fibers and 50% recycled aggregates from demolishing waste are suitable to produce concrete with good flexural strength.

6. No Conflict

The authors state no conflict of concern during the conduct of the research presented in this article and its processing of it for publication.

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