SSURJET

Sir Syed University Research Journal of Engineering & Technology
2021, Vol. 11, No. 2,
https://doi.org/10.33317/ssurj.288

Recycle Demolish Structure Concrete as Coarse Aggregate in Concrete with Incorporation of Glass Fiber

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Received February 04, 2021; Revised November 03, 2021; Accepted, November 17, 2021

Abstract

Waste recycling is an option to reuse the environmental impact resulting from the significant number of debris generated during the demolishing of old structures or illegal construction on government land. During the demolishing of concrete structure, millions of tons of waste concrete materials were generated which was required to be reused as a coarse aggregate in concrete by partial replacement of natural aggregates to reduce landfilling from waste material. The Capital Development Authority (CDA) of Pakistan has demolished the growing illegal construction on estate land. During the operation, 103 rooms, 23 kitchens, and 14 washrooms were completely demolished, a lot of concrete waste were generated, so for this purpose. The waste was demolished concrete was recycled in the form of coarse aggregate used in concrete to achieve the desired strength up to 3000 psi by adding some strength increasing material like glass fiber. In this research work, the Recycled Coarse Aggregates (RCA) from demolishing concrete structure was partially replaced by Natural Coarse Aggregate (NCA) in concrete. The experimental program started from the physical properties of all materials used in this research work, based on the knowledge of these properties. The mix design of concrete was prepared for the compressive strength of 3000 psi. Based on different procedures and literature review; the strength and workability of concrete decreased with percentage replacement of NCA with RCA. The loss in strength should be increased with strength increasing material by adding glass fiber up to 2 % by weight of cement used in concrete mix design. Glass fiber in the concrete act as reinforcement material. The mechanical properties of different sampling (0 % , 10 %, 20 %, 50 %, and 100 %) by substitution of NCA with RCA and addition of glass fiber were studied in the fresh and hardened state of concrete. The result shows that the strength of concrete increased up to 20 % replacement of NCA with the RCA and addition of glass fiber but further replacement shows a decrease in strength.

Index Terms: *Concrete, Recycled Aggregates, Compressive Strength, Flexure Strength, Tensile Strength.*

I. INTRODUCTION

Waste materials are the byproduct of industry; the materials which are unused from the used materials; the materials during demolation of structure which was not directly further used [1]. These waste materials are a global issue. Billion tons of waste material are generated each year. Aaccording to the report in 2003, the US produced 170 million construction waste of which 39 % are from residential and 61 % from other sources. According to a recent report China generates 1.13 billion, the United States generates 530 million and European Union generates 850 million tons of waste materials [2-4]. India annually generates 5.8 million construction waste material. Similarly Pakistan also generates million tons of construction waste material annually [5].

The issues related to environmental preservation are highlighted, despite great importance of construction sector in economic and social development. The construction sector has a very negative image. This sector generates environmental impacts during all stages of production chain i.e., from raw material extraction, manufacturing, transportation of materials, and final disposal of waste generated. The waste is generated during the execution of the works from demolished buildings at the end of their useful life. Thus, there is increasing pressure on this sector to incorporate more sustainability in the development of its activities i.e., not only by regulatory agencies perspective but also environmental issues should not be ignored. [6-8].

Instead of natural aggregates, recycled aggregates may be used. This practice is especially implemented in areas where natural aggregates are limited and are essential for reducing the environmental impact of raw material extraction. Moreover, recycling reduces the space needed in landfills for the disposal of such waste. The use of recycled aggregates for the production of new concrete is a way to reinsert this material into the production chain. The aggregates recycled concrete products have a great potential to be reused. Recycled aggregate can be used as substitute materials to decrease the use of natural aggregate. Many old constructions have exceeded their age and expected useability limits [9].

Although large cities are growing with time, the regulations used for creative buildings and networking have increased dramatically. The insistence of standard aggregates also increased with the vertical increase during the special structure. With the rapid evolution of infrastructure, the use of natural aggregates becomes more and more serious [10].

Pakistan generates solid waste between 0.283-0.612 kg/capita/day and the annual growth rate is 2.4 %. The four most common waste materials are industrial waste, municipal waste, hazardous waste, and agricultural waste. Amongst these waste materials, we are only focused on construction and demolition waste materials which is the main type of municipal waste [11].

Why it is so important in Pakistan to recycle demolish concrete as a coarse aggregate in concrete? The main reason is that a lot of structures demolished during current PTI government. The Islamabad Capital Territory (ICT) Administration and Police conducting operations against illegal construction. It demolished sixty-five commercial structures on 2,60,010 square meters land. According to CDA of Pakistan one service station, two three story plazas, three markets, twelve residential houses, and fifty shops were demolished because of their illegal status on Kashmir highway [12]. At the time of demolishing these waste materials are a serious issue to damp on land so it needs to be recycled in concrete material like as coarse aggregate [13].

The significance of this research work is to save natural source of aggregates for future generations. It also recycle waste construction material to protect our environment. The waste materials produced during the operation against illegal structures on government land was roughly 10 to 20 billion tons. The demolished structure's concrete was used as a partial replacement of coarse aggregate in concrete with different percentages (0 %, 10 %, 20 %, 50 %, and 100 %), also the mechanical property of concrete has been checked [14].

The usage of Recycled Coarse Aggregates (RCA) in concrete reduces the strength of concrete due to its shape and structural changes. Some strength increasing materials were added to concrete to increase the strength of concrete. The strength increasing material i.e., glass fiber of 2% was added by the weight of cement used in the concrete mix design [15].

In this research work, we used the demolished structural concrete as a coarse aggregate in concrete. How and where the demolished structural concrete was obtained were discussed in the introduction section. The demolished concrete was converted into coarse aggregate and its physical property were discussed in the material and methods section. The concrete mix design and the different number of beam and cylindrical samples were discussed in the methodology section. The mechanical property-related test of concrete was discussed in the test and result section. In conclusion, this section discussed the property of concrete with demolished waste aggregate and natural aggregate [16].

II. LITERATURE REVIEW

Waste generation is an inevitable stage of all industrial processes and human activities. Due to lack of recycling technologies, most of these wastes will certainly have improper disposal in nature. A fact that results in major environmental problems around the world [17].

Among various sectors of the economy, civil construction is in a very uncomfortable position regarding environmental issues. This position is not only because of the large amount of waste produced and dumped in the wild but also by a large amount of consumption of raw materials. In the European Union, construction contributes to eight twenty one million tons, i.e., approximately 33 % of the total waste generated by the world in 2012 [18].

In the same year, four eighty million tons of materials were the result of the industrial activities in the United States. In Brazil, waste construction is a burden on municipal public cleaning systems, with amounts representing 50 % to 70 % of the mass of municipal solid waste [19].

After the end of World War II in Germany, the tradition of recycling construction waste started to grow. To meet the need for aggregates, concrete from buildings demolished in the cities was crushed and reused. Too few, waste recycling proved to be very promising and the technique has spread to many nations [20].

The construction chain is responsible for the transformation of the environment into built structure that needs to be permanently updated and maintained. It is an activity of great social and economic importance. Like other industrial sectors, it is currently experiencing social and organizational pressures. Supervisors to adopt more sustainable postures, so the ambient tripod economy-society should be considered in an integrated manner [21].

On the other hand, we will have sustainable development; the challenge is to make the economy evolve, meeting the society's expectations and maintaining a healthy environment for the future generations. Increasing the sustainability of the sector depends on solutions at various levels in its chain articulated within a systemic view [22].

Recycling has the potential to reduce the volumes of waste disposed off in landfills; lower costs and preserve limited natural resources by reducing the amount of raw material extracted from the environment. Beyond, in addition, construction and demolition wastes are accompanied by undesirable materials, such as asbestos cement, construction plaster, and some chemical waste. This waste, when clandestinely deposited on vacant lots and watercourse slopes, cause impacts on the environment, enabling propagation of contamination vectors. When carried by surface water, it obstructs drainage pipes, causing floods and damage to society [23].

Technology transfer through the dissemination of knowledge by documentation and publications. It is an essential step in the aggregate application process of recycling. The success of recycling will also depends on collaboration between the various process actors; waste generators, potential consumers, government agencies, and research institutions. It is necessary to convince end consumers that new product has some competitive advantage and low environmental risks [24].

Recycling has become a measure constantly advocated by environmentalists. It is about to become a technological and even financial option within the construction process. Several actions by public authorities and business entities already seek to regulate demolition waste processing and material reuse. The main current uses, such as paving and landfill coverage. It require aggregates with low-quality requirements. However, for other applications such as concrete and mortar, scientific-technical knowledge is needed to provide practical applications [25].

In the European Community, actions concerning the reuse of waste from construction began to spread thanks to the reconstruction experiences of some cities after the end of World War II. Currently, several countries in Europe recycle the predominant part of the waste they generate. There is an effort to consolidate a single normative recommendation for the whole community. Lack of space for disposal in landfills, as well as the scarcity of natural aggregates, are factors that contribute to the implementation of recycling processes. Directive No. 2008/98/EC of the 18 European Union proposes, reuse and recycling of at least 70 % construction and demolition waste in all member countries by 2020. It is also expected that within this period new buildings will include at least 5 % of materials recycled [26].

Germany was one of the precursor countries in the practice of recycling . In 2008, 56 % of recycled aggregates were used as a base and sub-base in the construction of roads. The use of these materials as aggregates for structural applications is approximately 0.8 %. This data point out that the imposition of fees for disposal of these materials in landfills. It is a cost-effective tool to increase recycling. However, apparently it is not able to promote the generation of high-quality recycled materials [27].

In Germany, there are also works using concrete with recycled aggregates, such as the Vilbeler Weg Office Building. This building used a total of 461 m³ of concrete with recycled concrete aggregates, and the Waldspirale Residential Building, where 12000 m³ of recycled aggregate concrete was used on interior walls and floors [28].

In Brazil, recycling process of construction and demolition waste is recent and quite shy compared to first-world countries. However, it has great potential for enlargement. This delay compared to other countries is due to several factors. One is the environmental issue still seen as a problem of nature preservation. It mainly focused in forests and endangered animals, landfilling of materials air pollution control [29].

There is also the conception that a product made with the use of waste will have a lower quality than those produced by virgin raw materials. The feeling of risk of poor performance concerning the use of new technologies, low cost of natural aggregates, and lack of segregation culture are other barriers to recycling and reuse of construction waste [30].

Granular material from building waste processing that has technical characteristics for application in building, infrastructure, landfills, or other engineering works [31-33].

According to a resolution, construction waste falls under Class A-1. Considering disposal, these wastes should be recycled as waste or sent to landfill areas of civil construction to allow future use or recycling [34].

Some studies claim that replacing natural aggregates with recycled ones in the concrete has a detrimental effect. It decreases the values of properties such as compressive strength, elastic modulus, and tensile strength [35].

However, this should not be established reduction as an inevitable result of the use of recycled aggregates for the production of concrete. The values recorded for the hardened state properties of concrete produced from recycled aggregates depend on several factors. It includes origin, quality, substitution content of natural aggregate, moisture condition of recycled aggregate at the time of concrete production and healing conditions. When good quality recycled aggregates are used, the mechanical behavior is similar to that presented by conventional concrete [36-38].

A. Research Gap

Some of the previous research work on which different percentage replacement of Natural Coarse Aggregate (NCA) with Recycled Coarse Aggregates (RCA). Addition of glass fiber along with their strength parameter related to normal concrete were show in Table 1.

Table 1: Previous Research Work

Reference	**% Replacement of NCA with RCA**	**% Addition of Glass Fiber**	**% of 28 Days Strength (Reduction with Negative Sign and Vise Versa) w.r.t Normal Concrete**		
			Compressive	**Flexure**	**Tensile**
(Ali et al. 2019)	100 % NCA 100 % RCA	0, 0.25. 0.50 and 0.75	0, 8.83,7.86 & 6.08 0, 5.46, 8.20 & 4.78	0, 22.0, 19.91, & 18.45 0, 25.57, 24.19, & 21.85	0, 12.04, 15.36 & 13.97 0, 15.20, 18.42 & 16.72
(Khan 2005)	0, 25, 50 & 100		0, 7.88, 11.25 & 18.49	0, 3.21, 12.70 & 19.25	0, 0.27,2.41 & 4.28
(Garg and Sharma 2021)	0, 40, 60, 70, 80 & 100	0, 0.25, 0.25, 0.25, 0.25 & 0.25	0, -22.3, -34.6, -18.9, -8.2 & -29.30	0, -5.9, -5.2, -3.0, -7.4 & -21.4	0, --5.3, -4.3, -4.5, -1.8 &-23.4
(Al-Azzawi 2016)	0, 25, 50, 75 & 100		0, -6.7, -13.4, -18.5 & -30.9		, -6.55, -1.99, 3.07, 10.8 & 23.14
Geng et al. 2019)	0, 30, 50 & 100	0, 25, 50, 75	0, -21.4, -23.2 & -34.0		

III. MATERIAL AND METHODS

A. Material

The characterization of materials is essential for the preparation of samples by the substitution of different percentages of NCA with RCA. The following materials were used:

- Cement
- Natural Fine Aggregate
- NCA and RCA
- Glass Fiber

a) Cement:

The cement used is classified by the Lucky Cement Factory. This type of cement provides faster deformation and larger resistances in the first days of age.

The chemical and physical analysis parameters were obtained from the manufacturer and are presented in Table 2.

Table 2: Physical Property of Lucky Cement

Description	Values
Specific Gravity	3.2
Standard Consistency	32.95
Fineness Test	1.8
Initial Setting Time	28 mins
Final Setting Time	7 hrs. 50 mins

b) Natural Fine Aggregate:

The natural fine aggregate was natural sand. It is obtained from Karak source. These properties were shown in Table 3.

Tests were performed based on the properties of a specific mass, unit mass, water absorption, and the amount of passing fine materials in the sieve 75 µm according to the standards.

Table 3: Physical Property of Nature Aggregate Source (Karak)

Description	Values
Specific Gravity	2.6
Impact Values	12.1
Water Absorption	0.97
Bulk Density	0.69
Crushing Test	18.01
Abrasion Test	13
Size	20 m

c) NCA and RCA:

As a NCA, the available granite gravel was used in the region of Karak. The RCA aggregate used in the mixtures comes from the crushed concrete waste in hardened state from demolished illegal constructions in Islamabad.

The recycled material used in the work was obtained through a donation made by construction waste. The RCA and NCA physical properties were shown in Table 4.

Table 4: Physical Property of RCA and NCA

Description	RCA	NCA
	Values	Values
Specific Gravity	2.39	2.6
Impact Values	27.38	12.1
Water Absorption	4.98	0.97
Bulk Density	3.01	0.69
Crushing Test	30.05	18.01
Abrasion Test	15.95	13
Size	20 mm	20 mm

d) Glass Fiber:

Glass fiber available locally is used in the research. Table 5 shows the main characteristics of the glass fiber. It is obtained from the manufacturer located in Islamabad. In many research works glass fiber is used to enhance reinforcement property of concrete. It is used to increase the strength of concrete.

Table 5: Physical Properties of Glass Fiber

Description	Values / Remarks
Elastic Modulus	11022.868067 ksi
Glass Fiber Dia	0.6 cm
Specific Gravity	2.69
Length Available	0.6-1.8 cm

B. Methodology

In research work, the demolished concrete was collected from the structures demolished during the operation of CDA of Islamabad. The demolished big pieces were crushed and properly sieved like another previous research work to get RCA. The other materials (cement, fine aggregate, coarse aggregate, recycled coarse aggregate, and glass fiber) used in concrete were collected from the different available sources. Then laboratory tests were done according to ASTM C-143 Concrete Mix Design. The properties of other materials used in concrete were shown in Table 2 to Table 4. Following the same procedure of previous research for the testing of strength parameters, i.e., cylindrical and beam samples were prepared. According to ASTM C-143 Concrete Mix Designs were prepared and the ratio of concrete was shown in Table 5. According to the past research work, each sample was cured for 7, 14, and 28 days. Three samples were cast for each strength test and the final result i.e., the average of these samples was considered.

The numbers of samples were shown in Table 6.

Table 6: Quantity of Material

Material	Natural Coarse Aggregates (NCA) (kg/m ^{3})	Recycle Coarse Aggregates (RCA) (kg/m ^{3})
	3000 psi	
Cement	375	445
Fine Aggregate	780	610
Coarse Aggregate (20 mm)	1150.12	1100
Water	178.2	186.05
Cement: Fine: Coarse (Ratio)	1: 2.08: 3.0669	1: 1.37: 2.4719

The different % substitution of NCA in concrete samples with RCA and incorporation of glass fiber was shown in Table 7.

Table 7: Number of Samples, Percentage Substitution of NCA with RCA, and addition of Glass Fiber

Samples Specification		Duration (Days)	Compressive Test	Flexure Test	Tensile Test
0 % Substitution of NCA with RCA		7	3	3	3
		14	3	3	3
		28	3	3	3
2 % Addition of Glass Fiber by weight of Cement on each sample except 0 % Substitution of NCA with RCA	10 % Substitution of NCA with RCA	7	3	3	3
		14	3	3	3
		28	3	3	3
	20 % Substitution of NCA with RCA	7	3	3	3
		14	3	3	3
		28	3	3	3
	50 % Substitution of NCA with RCA	7	3	3	3
		14	3	3	3
		28	3	3	3
	100 % Substitution of NCA with RCA	7	3	3	3
		14	3	3	3
		28	3	3	3
Total Samples			**45**	**45**	**45**

IV. TESTS AND RESULTS

A. Slump Test

For workability, the Slump test is used, which is a physical parameter of concrete. It directly affects the strength and finishing surface of the concrete. The slump test mainly depends on the water-cement ratio. It also depends upon the aggregate in concrete. The aggregates in concrete absorb water so in this case; we used RCA of various percentages to replace NCA. For this purpose, a slump test is used to check the workability of concrete. The slump values of different mixes were shown in Table 8 and the graphical result was also shown in Figure 1.

Table 8: Slump Value of Mixes (By different percentage substitution of NCA with RCA)

Mixes	Addition of Glass Fiber	Slump Value(mm)
0 % Substitution of NCA with RCA		86
10 % Substitution of NCA with RCA	2 % Addition of Glass Fiber by Weight of Cement on each sample except 0 % Substitution of NCA with RCA	74
20 % Substitution of NCA with RCA		72
50 % Substitution of NCA with RCA		88
100 % Substitution of NCA with RCA		89.5

The workability of concrete increased by substitution of NCA in concrete with RCA up to 20%. The percentage increase of RCA in concrete causes the workability of concrete to decrease. This is due to high water absorption of RCA (water absorption of RCA is 4.98 as shown in Table 4).

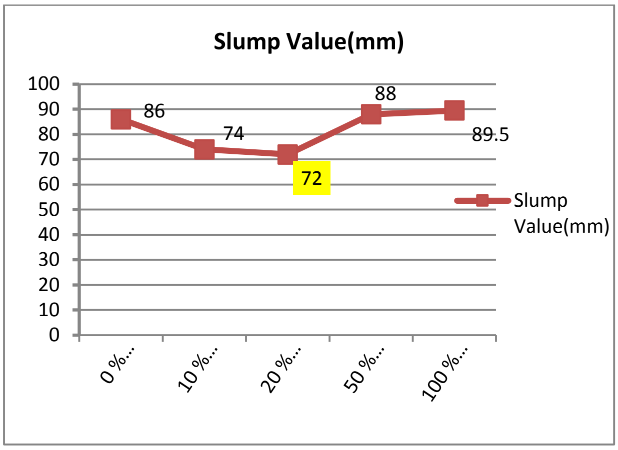

Figure 1: Graphical Results of Slump Test

B. Compressive Strength

The compressive strength at 7, 14, and 28 days was determined by the Standard Strength Test (ASTM C-39). It is a test of easy execution, universally accepted as a strength index of concrete. Besides the inherent importance of compressive strength in concrete elements. The other material properties are associated with it. The compressive test values of different mixes were shown in Table 8 and the graphical result was shown in Figure 2.

Table 9: Compressive Test Value of Mixes (By different percentage substitution of NCA with RCA)

Mix Id	Addition of Glass Fiber	Compressive Strength (Psi)		
		7 days	14 days	28 days
0 % Substitution of NCA with RCA		2111	2511	2967
10 % Substitution of NCA with RCA	2 % Addition of Glass Fiber by Weight of Cement on each sample except 0 % Substitution of NCA with RCA	2258.56	2656.56	2977.56
20 % Substitution of NCA with RCA		2285.67	2675.67	2985.67
50 % Substitution of NCA with RCA		2045.45	2455.45	2845.45
100 % Substitution of NCA with RCA		2036.8	2448.8	2759.8

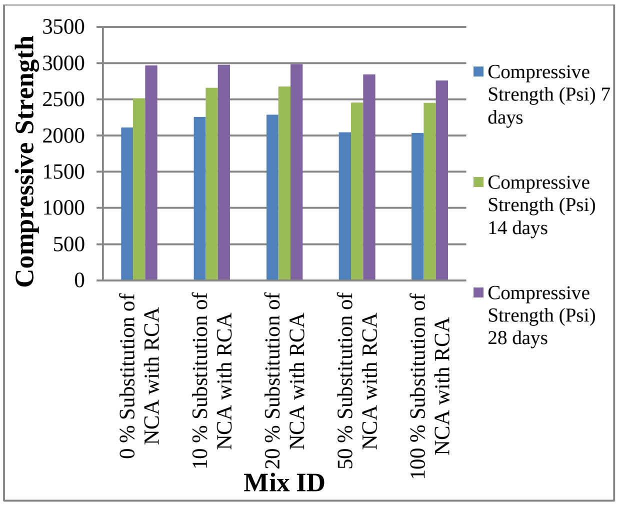

Figure 2: Graphical Results of Compressive Test

The result of different samples shows that the compressive strength increased up to 20 % by replacement of NCA in concrete with RCA and a 2 % addition of glass fiber by weight of cement. Normally the strength of concrete decreases with RCA due to reduction of crushing strength (30.05 shown in Table 4). The strength increased up to 20 % by replacement of NCA with RCA in concrete was due to the addition of glass fiber. Many research works show that the strength of concrete increased with glass fiber because glass fiber acts as a reinforcement material in concrete.

C. Tensile Strength

The tensile strength at 7, 14, and 28 days was determined by the standard ASTM D-638. Three specimens were broken from each mixture belonging to the second production phase of the concrete of the work. The tensile test values of different mixes were shown in Table 10 and the graphical result was shown in Figure 3.

Table 10: Tensile Test Value of Mixes (By different percentage substitution of NCA with RCA)

Mix Id	Addition of Glass Fiber	Tensile Strength (Psi)		
		7 days	14 days	28 days
0 % Substitution of NCA with RCA		2732.61	2302.08	1910.46
10 % Substitution of NCA with RCA	2 % Addition of Glass Fiber by Weight of Cement on each sample except 0 % Substitution of NCA with RCA	2742.33	2435.53	2044
20 % Substitution of NCA with RCA		2749.8	2453.05	2068.53
50 % Substitution of NCA with RCA		2620.66	2251.16	1851.13
100 % Substitution of NCA with RCA		2541.78	2245.06	1843.3

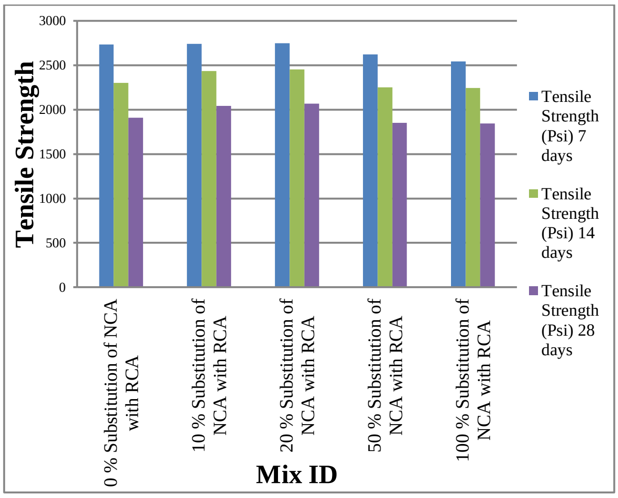

Figure 3: Graphical Results of Tensile Test

The tensile strength was normally decreased by partial replacement of coarse aggregate with RCA in concrete. In this research work, strength increases with addition of glass fiber. It is because of glass fiber acts as reinforcement in concrete. The tensile strength increased up to 20 % by replacement of coarse aggregate shown in Table 10 and Figure 3.

D. Flexure Strength

The tensile strength at 7, 14, and 28 days was determined by the standard ASTM C-293. It analyze the pore volume concrete permeable from the amount of water absorbed by material. The tensile test values of different mixes are shown in Table 11 and graphical result was shown in Figure 4.

Table 11: Flexure Test Value of Mixes (By different percentage substitution of NCA with RCA)

Mixes	Addition of Glass Fiber	Flexural Strength (Psi)		
		7 Days	14 Days	28 Days
0 % Substitution of NCA with RCA		327	402	510
10 % Substitution of NCA with RCA	2 % Addition of Glass Fiber by Weight of Cement on each sample except 0 % Substitution of NCA with RCA	350	425	512
20 % Substitution of NCA with RCA		354	428	514
50 % Substitution of NCA with RCA		317	393	489
100 % Substitution of NCA with RCA		316	392	475

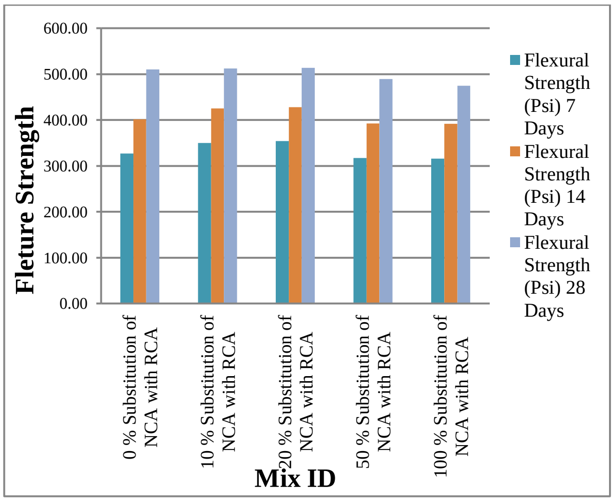

Figure 4: Graphical Results of Flexure Test

Similarly, Flexure Strength decreased with partial replacement of coarse aggregate with recycling coarse aggregate in concrete. The main Flexure Strength increase is due to glass fiber just like the previous research work.

From all results of workability and strength tests, the highest workability and strength of concrete achieved by 20 % replacement of NCA in concrete with RCA. The workability (Slump value), compressive, flexure and tensile strength of 20 % by substitution of NCA with

RCA sample is 16.28 %, 0.63 %, 0.625 %, and 7.24 % respectively. This increased from normal concrete (0 % substitution of NCA with RCA and no addition of glass fiber).

V. CONCLUSION

In this research, demolished concrete of illegal construction in Islamabad region was further used as a coarse aggregate in the concrete.

The highest value of workability and the strength was 20 % by substitution of NCA with RCA and 2 % addition of glass fiber in the sample. Since the recycling of waste or demolishing concrete was beneficial in the form of useable concrete.

According to the mix design ratio (1:2.08:3.0669), the quantity of coarse aggregate in cubic meters was 0.498 m^3. Therefore, the quantity of RCA in one cubic meter concrete sample of 20% by substitution of NCAwith RCA was 0.0996 m^3 (20 % X 0.498 = 0.0996 m^3).

Therefore, it is concluded that waste structure concrete can be recycled in the form of coarse aggregate without reduction of strength. It also to keep environment safe and healthy.

The strength of concrete was reduced by using RCA. However, reduction was controlled with some strength-increasing materials like glass fiber. In the future, it can be checked with other materials (like carbon fiber, iron slag, ferrous slag, etc.) to increase the quantity of RCA without reduction in strength. In this way, it will be possible to recycle demolish concrete more and more.

VI. RECOMMENDATIONS AND FUTURE DIRECTIONS

During this research work, it was concluded that the following recommendation should be considered for further improving the mechanical property of concrete:

1) It is recommended that the replacement of NCA in concrete with a RCA up to 20 % give us an acceptable mechanical property.
2) In the future a recommendation is that; change the shape (agular or rounded) of recycled coarse aggregate and check their mechanical properties.
3) Also, in the future a research work needs to be conducted to check durability test of RCA in concrete and compared with normal concrete.

Acknowledgment

I would like to thanks almighty Allah first and then all the co-authors for their full support and hard work that we have completed this research study successfully.

Authors Contributions

Safdar Iqbal contribution to this study was the concept, project administration, paper writing and supervision. Umer Majeed performed data collection, methodology, samples collection. Haris Khan performed the validation, samples analysis, and preparation laboratory equipment. Sajid Ullah contributed in arranging and transporting the materials and figure sketching of the results. Beenish Jehan contribution was data collection and literature review.

Conflict of Interest

There is no conflict of interest between all the authors.

Data Availability Statement

The testing data is available in this paper.

Funding

This research did not receive any specific grants from funding agencies, the public, commercial, or not-for-profit sectors.

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