Jestr

Journal of Engineering Science and Technology Review 16 (4) (2023) 85 - 93

Review Article

JOURNAL OF
Engineering Science and Technology Review

www.jestr.org

The Impact of Fiber Reinforcement on Fresh and Physical Properties with Durability of Recycled Coarse Aggregate Concrete: A Review

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Received 4 May 2023; Accepted 30 June 2023

Abstract

Physical and Chemical properties of fiber-reinforced recycled aggregate concrete is investigated and presented in this manuscript. Due to significant growth potential of recycled aggregate in concrete industry several researchers paid their attention towards this area in recent years. The mechanisms by which Physical and Chemical characteristics and durability properties of fiber-reinforced concrete could be improved through different fibers in concrete has been investigated by various authors. So, in the presented paper an attempt has been made for review of their work and explore the possible areas by which significant improvement in strength can be done in recycled aggregate concrete. The Recycled Aggregate Concrete's flexural strength and tensile strength have significantly improved consequently. According to the study, fiber-reinforced recycled aggregate performs better than regular recycled aggregate concrete at higher temperatures. However, fibre reinforced aggregate has been proven to absorb water far more than natural aggregate concrete, according to research. Additionally, it has been shown that the fibres stop and prevent the spread of concrete cracks. The outcome supports the satisfaction with the mechanical performance of the recycled aggregate concrete as well as the concrete manufacturing.

Keywords: Recycle coarse aggregate, Physical property, Mechanical property, Durability, Interfacial Transition Zone ITZ.

1. Introduction

Reusing of demolition waste play important role to preserving non-renewable natural resources while the rate of demolition increases regularly. Utilizing recycled aggregate (RA) is unquestionably a significant step towards sustainable growth in concrete industry and management of building waste in current situation. A crucial substitution for natural aggregate that significantly contributes to environmental preservation is recycled aggregate. Use of RAC decreases need for gravel and environmental pollutants, enhancing structure's long-term viability. In creation of vibrated recycled aggregate concrete, use of Recycled Concrete Aggregate (RCA) as a substitute for Natural Aggregate has been thoroughly studied. Idea of fibre reinforced concrete (FRC) is not new. In biblical era, it was used to cement building materials made of straw and horsehair. There are several fibre choices for concrete reinforcement available on market today for building industry. These include steel, basalt, and micro- and macro-synthetic fibres. Finding precise fibre needed for a certain application may be more challenging.

Crushed concrete, crushed masonry, and mixed demolition debris are three categories into which Silva et al [1] have divided construction and demolition wastes. Matias et al [2] looked at how various crushing techniques affected shape index of aggregate and ultimately how well concrete performed. For instance, utilizing same crushing technique results in RCA that is more rounded in form than Natural Aggregate. According to Hossain et al [3], a minor amount of RA (10%) enhanced compressive strength because larger amount of water absorbed by RCA, including water-cement ratio ITZ, allowed for better internal curing. However, when RA quantity above 30%, strength fell as a result of the concrete creating more porosity. RA offers more water absorption than Natural Aggregate (NA), for this reason. As a result, when RA has been added to concrete mixture, workability of concrete is decreased.

When RAC and NAC were tested in terms of compressive strength, splitting tensile strength, flexural strength, water absorptivity, drying shrinkage, and chloride-ion penetration, some researchers discovered that RAC had equivalent or even better mechanical and durability attributes. Huda and Alam et al [4] discovered no appreciable difference between Poisson's ratio and Modulus of Elasticity (MoE) for RAC up to 50% replacement level of RA. Poisson's Ratio of RA was also noted by Zhou and Chen et al [5] to be comparable to or even slightly higher than NAC. According to Alam et al [6], compressive strength of mixture containing 25%–50% was comparable to the control mix. Additionally, Limbachiya et al [7] note that ideal RA content was up to 30%. Some standards permit manufacturing of up to 60 MPa of concrete with 100% RA replacement [8] [9], whereas other standards only permit production of 10 MPa of concrete using 100% RCA [10]. RA is employed when necessary, strength of concrete is less than 27Mpa, according to Choi & Yun et al [11]. According to Xiao et al [12], suitable mix design and special care are kept in mind during building phase for recycled aggregate concrete.

Because it may reduce brittleness of traditional concrete, fibre reinforced concrete is a novel material that has gained favor in recent years. Concrete's ductility, toughness, impact resistance, and energy absorption capacity are some of issues that FRC addresses. Mechanical and durability characteristics of concrete's compressive strength, flexural strength, tensile strength, and creep behavior are all

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ISSN: 1791-2377
doi:10.25103/jestr.164.11

improved by addition of fibre. While fibres are employed to control the spread of fractures in concrete, which enhances structural integrity and ductility. Steel fibre, synthetic fibre (Polypropylene fibre, nylon fibre, carbon fibre, asbestos fibre, etc.), glass and ceramic fibre, and natural fibres are only a few of several forms of fibre that are utilized in construction. Steel Fibre Reinforced Concrete (SFRC) can spread localized stresses and create strong and permanent surfaces in concrete mixture, which reduces crack propagation on, increases impact resistance, and improves freezing and thawing resistance of concrete. As a result, steel fibres are most used of all fibres. While some earlier researches have shown that addition of steel fibres to concrete has improves structure's tensile strength, ductility, toughness, and fatigue life.

Ordinary concrete, as previously established, has lesser tension and is fragile by nature. As a result, between commencement of a fracture and its collapse, Steel Fibres in Self-Compacted Fiber Reinforced Concrete (SFRC) enable high-level stress redistribution, and greatly aid structural deformation and it also enhance ductility and toughness (Energy Absorption). Steel fibres used in concrete should, according to ACI 544.1R, have an aspect ratio (i.e., the ratio of length to diameter) ranging from 20 to 100 roughly, and length dimension should be in range of 6.4mm to 76mm in concrete mix, the mechanical characteristics of material improves as fibre content rises, according to Zheng et al [13], although rate of improvement was higher when fibre level was less than 1%. The flexural strength of ultra-high performance reinforced concrete beams was experimentally determined by Lee et al [14] under static and impact loads. According to his research, fibre inclusion enhanced energy dissipation capability and impact and static load resistance. Fibres bridged cracks and reduced crack propagation during first loading phases, hence boosting concrete's strength. As stress was raised, fibres' apparent strength and toughness increased due to dispersion of microcracks.

It was noted that qualities of new concrete, such as workability and air void, will be affected by use of fibres in concrete. It can be shown that workability of concrete has an antagonistic relationship with fibre contents. According to Guerini et al. [15], Polypropylene (PP) fibre had a worse impact on workability than steel fibre. Udgunoglu et al [16] note that unit weight of SFRC decreases due to high air void content, long fibres that hinder fibre dispersion, and fibre content in concrete.

In order to increase mechanical, physical, and long-term durability of concrete and increase its ductility, toughness, and capacity for absorbing energy through the phenomena of bridging, PP fibre is primarily employed in concrete. According to Alhozaimy et al [17], PP fibre enhances concrete's toughness, initial crack resistance, and impact resistance while having a minor influence on compressive and flexural strength. According to research by Mazaheripour et al [18], adding PP fibre to concrete can lower slump values by up to 40%. They evaluated how PP fibre affects qualities of lightweight self-compacting concrete both while it was new and after it had hardened. They also noted that while PP fibre had no effect on the concrete's compressive strength, it did boosts material's tensile and flexural strengths.

Steel fibre is most often utilized fibre in concrete, according to several studies, since it may increase material's properties. However, steel fibre is expensive and not extensively utilized in underdeveloped nations since it is not locally available. Numerous studies have looked at impact of various fibre kinds on mechanical and durability characteristics of concrete. According to Meesala et al [19], steel fibres outperform other types of fibres including woolen fibre and glass fibre in terms of compressive strength, split tensile strength, and flexural strength. In addition, Gao et al [20] noted that impact of PP fibre on compressive strength was determined to be negligible compared to upward trend of compressive strength with addition of steel fibre. In contrast to PP fibre, improvement in split tensile strength was more noticeable with steel fibre.

2. Literature Survey

Numerous studies have been conducted on RCA by academics in an effort to distinguish between traditional method of building and sustainable construction process. This paper attempts to review by various Researchers in this part. In their investigation, Sharif and Kareem et al [21] discovered that old mortar's fragility weakened link between it and new mortar, which in turn lowered RAC's compressive strength. Additionally, research show that RAC's split tensile strength and flexural strength decreases. According to Mohd. Abed and Rita et al [22] Modulus of Elasticity (MoE) of Concrete was more significantly impacted by substitution of RCA than other mechanical characteristics of Concrete when NA was 20% replaced with RCA. They also discovered that optimum approach to employ RCA in concrete is Self-Compacting High Strength Concrete (SCHSC). Hybrid Fibre has greater mechanical and lasting qualities than nominal Fibre used in High-Performance Concrete, according to Dehong and Yanzhong et al [23]. Additionally, it was shown that using a single fibre in HPC had a negative synergy effect when compared to using a hybrid fibre. In their research, Chunsheng and Yanzhi et al [24] discovers that ultimate failure mechanism of Basalt Fiber Reinforced Recycled Concrete (BFRRC) specimen's cubic compression was quadrangular pyramid failure, and it was also discovering that concrete's splitting strength is decreased by increasing of replacement of RCA. Additionally, they discover that performance of RC decreased as RA replacement increased, however addition of basalt fibre significantly boosted concrete strength. Another researcher, Jawad and Oasama et al [25], discovers in their investigation that addition of Nylons Fibre improvs concrete's resistance to bleeding and segregation but decreased its capacity for filling and passing. Additionally, they discovered in their research that addition of nylon fibre improves mechanical and durability features of self-compacting fibre reinforced recycled concrete (SCFRRC). In their research, Jose A. and Isidro A. et al [26] discovered that using fly ash instead of cement significantly improves concrete's mechanical qualities. Additionally, they discovers that concrete is more malleable when creep temperature of Self Compacting Recycled Aggregate Concrete is raised from 200°C to 600°C. Md. Abed and Jan fort et al [27] noted in their research that replacing cement can reduce CO_2 emissions and reduce project costs by up to 17% by replacing both cement and aggregate. Additionally, it states that using waste perlite powder and RCA together produces concrete that performs better than regular concrete. In their investigation, Victor and Vanesa et al [28] discovers that application of fine RCA reduces surface hardness of concrete owing to presence of mortar and that angular form of fine RCA limited SCC's capacity to slump flow. The hammer rebound index could be correctly connected to

Compressive strength of Concrete, they evaluated by simple regression between two, as seen by high coefficient R_2 in fourth and fifth columns. with other researcher, Md. Jahidul and Kamrul et al [29], noted in their studies that plastic shrinkage of the concrete was minimized with integration of fibres up to proper quantity in concrete matrix and also noted Under compression, every fibre exhibits same stress-strain curve pattern. Compared to galvanized iron fibre reinforced concrete, polypropylene fibre reinforced concrete has a higher strain capacity. While adding polypropylene and galvanized iron fibres improves mechanical and durability characteristics of concrete mix.

3. Current Material Requirement

3.1. Recycled Concrete Aggregate

The most widely utilized substance worldwide is aggregate. It is an inert substance that embodied least amount of energy during production of concrete. Main issue in current situation is concrete structure's demolition waste. Concrete's degradation as a result of prolonged and severe exposure to unfavorable environmental conditions is what ultimately causes destruction of concrete. Additionally, old constructions that did not adhere to contemporary construction norms and practices are being torn down. Construction and demolition (C&D) waste is term for vast amount of solid waste produced during construction and demolition. It is crucial to find a purpose for significant amount of garbage produced by building and demolition since, if not, it will be disposed of in landfills for an extended length of time. Long-term C&D waste disposal in open spaces is neither convenient for society or environment. To lessen strain on natural resources, another method of handling C&D waste must be created. It must be demonstrated that using C&D waste in concrete is a positive step towards achieving sustainability and cleaner manufacturing in building construction sector. The procedure for production of RCA is shown in Fig. 1.

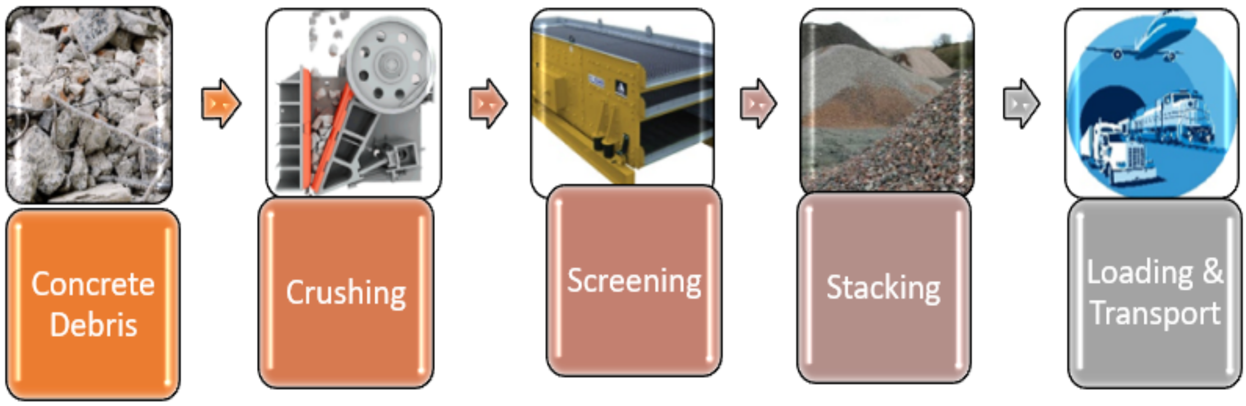

Fig. 1. Process of Recycled Aggregate.

After undergoing necessary processing and grading to produce a size that is comparable to coarse aggregates to create recycled concrete aggregate, C&D waste can be employed in area of building. In concrete, RCA can be a potent substitute for NCA, and several research have been done on impact of RCA on concrete. Due to ancient mortar that was still linked to aggregate when RCA was acquired, its qualities are lower and less than those of NCA. Mortar phase, aggregate phase, and interfacial transition zone between aggregate and new mortar matrix and existing old residual mortar matrix are three phases that make up RCA-based concrete. Due to residual mortar, RCA-based concrete has a reduced compressive strength, a greater porosity, and a higher water absorption rate, which causes a weak zone to emerge.

India is nation with world's fastest-growing population and most promising economy; thus, it has to build quickly to satisfy its needs. Existing buildings are swiftly demolished and new infrastructure is built, which causes a significant quantity of C&D trash to be produced. Every year, over 150 million tonnes of C&D garbage are produced in India. Only 6500 tonnes of that total are recycled. The management of C&D trash in India is a careful issue because our nation's recycling capability is only 1% of total garbage produced annually. Similar circumstances exist in many developing nations throughout world. In construction sector, recycling C&D waste is a fundamental prerequisite for achieving sustainability in a variety of ways. There will be less of an influence on environment when C&D waste is disposed of in landfills and when natural resources are mined. Use of RCA will guarantee preservation of natural resources and assist us in striking a balance between their use and their availability. Use of RCA in building ensures success of endeavor for sustainable construction and aids in creating a green and clean environment.

3.2. Fiber Reinforcement Types and Properties

Thread By mixing in a specific quantity of chopped fibres that have been randomly distributed, reinforced RAC may be created. Although fibres have reinforcing effects on RAC, there is a strong correlation between fibre characteristics, fibre quantity, and fibre dispersion in Concrete matrix. Ideal dose of various fibres varies, and they each have a unique impact on RAC characteristics. In order to prevent formation and spread of interior microcracks, fibres can efficiently connect RA and cement mortar to RAC's overall compactness. Fibres can successfully increase concrete's flexural, tensile and compressive strength. There is a significant amount of heat hydration created during concrete casting process, and because of excessive water used, shrinkage cracks will develop. However, when right quantity of fibre is added to concrete, it prevents development of fractures and enhances concrete's compactness since fibres can function as a bridging agent.

In addition to qualities of fibres themselves and their reinforcing impact on RAC, additional aspects like as fibre content, fibre length, and others should be taken into account when using fibres in concrete.

4. Properties of Material

4.1. Physical Properties of RCA and NA

The recycled concrete aggregate includes both crushed and uncrushed original aggregates as well as a tiny amount of hardened mortar and a coating of mortar.

Table 1. Properties of RCA reported by various literature.

	Workability	Mechanical Properties						Durability Properties			
	Slump	Compressive Strength	Tensile Strength	Flexure Strength	Density	Porosity	Elastic Modulus	Chloride Penetration	Carbonation Test	Acid Attack	Water Absorption
Md. Jahidul Islam et al [29]	✔	✔	✔	✔	✔	-	✔	-	-	-	-
Xinglong yao et al [30]	✔	✔	✔	✔	-	-	✔	-	-	-	-
Yaunxun Zheng et al [31]	✔	✔	✔	✔	✔	-	✔	-	-	-	-
Jawad Ahmed et al [25]	✔	✔	✔	✔	✔	✔	✔	-	✔	✔	✔
Chunsheng Zhang et al [24]	✔	✔	✔	✔	✔	-	✔	-	-	-	-
Mohammed Abed et al [27]	✔	✔	✔	✔	✔	-	✔	-	-	-	-
Chndra sekhar das et al [32]	✔	✔	✔	✔	✔	-	✔	-	-	-	-

Gravity increases somewhat with an increase in strength of primary concrete, source of RCA. Water absorption of RCA is significantly higher than that of Natural Aggregate because mortar phase of concrete has a higher porosity than aggregate phase. Mortar phase separates from aggregate phase during crushing of concrete because bond between aggregate and mortar is weaker in lower-strength of parent concrete. Significant properties of RCA reported by different scholars is elaborated in Table.1.

Mortar particles are crushed to small particle sizes (less than 4.75 mm size), which separate after sieve. In higher grade of parent concrete the bond between mortar and aggregate is stronger as compare to lower grade of concrete from which RCA is made. This results in an increase in size and number of mortar particles in RCA. While Specific Gravity of Aggregate decreases in value as amount of mortar particles in RCA grows. Fineness modulus of RCA ranges from 6.03 to 7.2, which was greater than NA, which makes it difficult to use. Shrinkage has also been discovered to be higher in RCA, making it difficult to use in building business.

It has also been observed by several researchers in earlier studies that because to presence of mortar in parent concrete from which RCA was made, RCA's resistance to crushing, impact, and abrasion is substantially lower than that of NA.

Table 2. Properties of RCA reported by various literature.

References	Apparent Gravity	Bulk Density (kg/m³)	Fineness Modulus	Aggregate Crushing Value	Water Absorption (%)	Impact Value (%)	Porosity (%)
Md. Jahidul Islam et al [29]	2.90	-	6.85	-	6.38	-	-
Yuanxun Zheng et al [31]	2.55	-	-	16.3	5.3	-	49.6
Chandrasekhar Das et al [32]	2.24	-	-	36.21	5.53	27.41	-
Sherif Yehia et al [21]	2.5	-	-	35	8.5	-	-
A. K. Padmini et al [33]	2.52	1536	-	26	-	25	44

Resistance to mechanical activities and maximum size of aggregate both diminish as a result of presence of parent concrete's mortar particles. When compared to bigger size aggregate, it can be seen that smaller aggregate particles with a higher surface area enable thicker mortar coatings. According to Indian Standard IS 2386 Part IV, aggregate impact of concrete used in non-worn surfaces should not exceed 45% and maximum impact value for concrete used in wearing surfaces, such as roadways, runways, and tunnels, should not exceed 30%. However, Aggregate Impact Value should not exceed 22% when aggregates are utilized for M65 and above. According to British Standards BS 882-1992, aggregate should have an impact value of less than 25% when used in heavy-duty floors, 30% when used in wearing surfaces, and 45% when used in other concrete surfaces. Accompanying Table 2 provides a summary of the many physical characteristics of RCA that have been documented by various researchers in their study articles.

4.2. Physical Properties of Fiber Reinforcement

This reinforcement addresses issues associated with brittle nature of traditional concrete, such as toughness, ductility, impact resistance, and energy absorption capacity, concrete is a relatively sophisticated idea that is gaining appeal. The mechanical and durability characteristics of concrete, such as its tensile strength, flexural strength, creep behavior, and compressive strength, are improved by inclusion of fibres. at various scales, performance of concrete is improved by inclusion of various types of fibres in Concrete matrix. While inclusion of fibre in concrete prevents fractures from spreading. Market-available fibres include steel fibre, carbon fibre, synthetic fibre (PP), nylon fibre, and others with a variety of characteristics. Steel fibres in concrete provide finished product robust, durable surfaces, limit fracture propagation, boost impact resistance, and resist freezing and thawing.

Steel fibres improved tensile strength, ductility, toughness, and fatigue life of concrete, according to several studies. Polypropylene (PP) Fibre, second most used fibre in concrete, is used to increase material's ductility, toughness, and capacity for absorbing energy through phenomena of bridging. PP fibre increases concrete's toughness, fracture resistance, and impact resistance but has little impact on concrete's compressive strength and flexural strength. Numerous studies have shown that adding PP fibre to concrete can lower the slump value by as much as 40%. Table 3. defines distinct characteristics of many fibres.

Table 3. Properties of fiber as per various literature

Fiber	Density (gm/cm³)	Diameter (μm)	Tensile Strength (MPa)	Elastic Modulus (GPa)	Elongation (%)	Resistance of Acid and Alkali
Steel Fiber	7.8	200	1270	200	3.4-4	Moderate
Carbon Fiber	1.78	7	3530	230	1.5	Good
Polypropylene Fiber	0.91	100	472	5.8	19.9	Excellent
Ployvinyl Alcohol Fiber	1.3	39	1600	39	7	Good
Ultra-High molecular weight polyethylene fiber	0.97	20-50	3000	100	2.8	Excellent

4.3. Microstructural property of Recycled Aggregate Concrete

Concrete's hardened and durability properties are governed by concrete's intrinsic microstructure. Analysis of material's microstructure is very important from a performance standpoint because there are numerous features that affect performance of concrete. Due to aggregate that is attached to mortar, study of RCA's microstructure is more complicated than that of NCA. Interfacial Transition Zone contains a number of extremely minute intrinsic grooves, pores, and cracks, as shown by scanning electron microscopy (SEM). Due to presence of cracks and grooves in ITZ of Concrete, minor properties of RCA compared to NCA are extremely weaker and get affects concrete's properties. SEM analysis reveals that between aggregate and adhered mortar, there are two ITZ in case of RAC.

4.4. Fresh Properties of Recycled Aggregate Concrete (RAC)

When recycled aggregate concrete is used in place of conventional concrete, the phrase "workability" is crucial. Scientists [7, 32, 34] have studied the impact of RCA and fibres on the workability of concrete. Limbachiya et al [7] and C. Das et al [32] founded as the replacement level of the RCA from NCA increases, the workability of concrete that has had RCA replaced declines. It was discovered that because of the RCA's extremely porous surface and the presence of old leftover mortar, which absorbs water from the concrete mix and reduces the concrete's workability, the aggregate's potential to absorb water is significantly higher. Which results decrease in workability of fresh RAC and further decrease in compressive strength of hardened RAC due to loss of water for heat of hydration. To counter this, on RCA have sprayed with water a day before usage using a sprinkler system, and then it covered with a plastic sheet until employed in the construction of concrete in order to maintain a high humidity level. 80 percent of their overall capacity for absorption is the acceptable amount of moisture [34]; However, the most crucial aspect are fact that aggregates used as moist in order to lower their potential for absorption [35]. Recycled aggregate absorbs some free water since its initial moisture content was mild. and improved the interfacial connection between the aggregates and cement by lowering the initial w/c ratio in the ITZ [36].

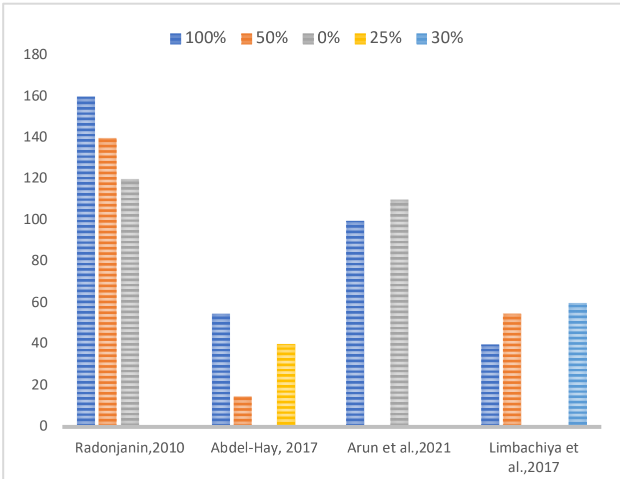

Fig. 2. Recycled Aggregate Concrete's Workability by Various Authors.

4.5. Mechanical Performance of RAC

4.5.1. Compreesive Strength

Any concrete's compressive strength is regarded as an indicator of material's overall effectiveness. Compressive strength of concrete is regarded as being crucial to overall mechanical qualities of material since it immediately reflects any concrete structure's capacity to withstand external pressure. As can be seen, aggregate makes up bulk of concrete and directly affects material's compressive strength. Because it makes up the bulk of the concrete's volume, coarse aggregate is crucial to development of compressive strength.

Because of lower bond force between aggregate and mortar of RCA, the strength of concrete decreases. Further, it is observed that replacing of RCA from NCA in concrete results in a drop in strength of concrete while increasing replacement level of RCA in concrete. Studies have shown that adding fibre to concrete improves mechanical performance of concrete while also increasing its strength.

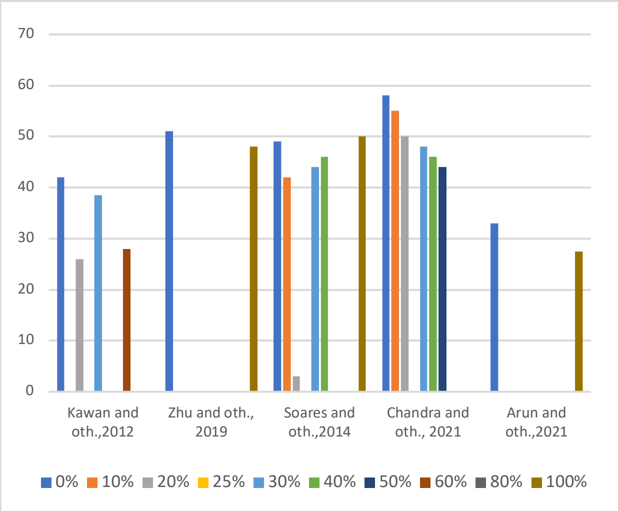

Fig. 3. Result for Compressive Strength of Recycled Aggregate Concrete by various Authors.

Literature [1, 23, 33] demonstrate that adequate gradation of aggregate in concrete results in higher mechanical performance of concrete. Therefore, it can be concluded that from perspective of strength, right gradation of aggregate in concrete is highly significant. In their investigation on RCA-based mixtures, Silva et al [1] discovered that performance of RCA as a replacement degrades as amount of recycling's of aggregate rises. In their investigation, Padmini et al [33] discovered that replacing RCA with NA in concrete decreased compressive strength comparable to parent concrete by 10% to 35% for various combinations. In their investigation, Dehong wang et al[23] came to conclusion that adding more basalt fibre to concrete increases concrete's compressive strength.

4.5.2. Flexural Strength

Flexural strength is a crucial factor to consider while analyzing concrete's resistance to bending failure. Flexural strength development is a crucial component of concrete design. To calculate flexure strength for each mix of concrete, three point loading was applied to a simple concrete prism. It has been shown that concrete has great compressive qualities but weak flexure resistance. Concrete has a flexural strength that ranges from 10% to 20% of its compressive strength. Studies [35, 38] have shown that RAC has a slightly different compressive-flexure ratio than regular concrete, but a lower flexure strength. When compared to NCA, the RCA has a weaker Interfacial Transition Zone (ITZ), which has an impact on concrete's flexural strength. According to research published in the literature, adding fibres to concrete improves its ability to bend. According to Sriram et al [35] addition of fibre to concrete can boost its flexural strength by up to 30%. According to Sivakumar et al [38], adding proper quantity of fibre to concrete may successfully stop development and growth of microcracks and boost material's flexural strength by 15% to 20%. It is evident that concrete's flexural strength decreased by 19.25% and 16.11% at 7 days and 28 days, respectively, depending on replacement ratio of RCA from NCA at varied levels of 15%, 30%, 45%, and 60%.

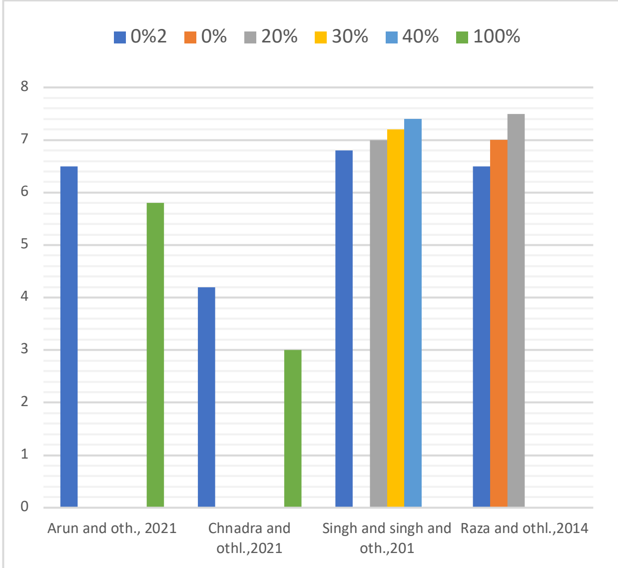

Fig. 4. Flexural Strength of Recycled Aggregate Concrete by Various Authors.

4.5.3. Splitting Tensile Strength

Another crucial mechanical performance aspect of concrete that controls size and severity of cracking is its split tensile strength. To assess load at which concrete members may break, split tensile strength is measured. Tensile strength of concrete decreases with degree of recycled concrete aggregate (RCA) substitution over natural coarse aggregate (NCA). In their work, Dimitriou et al [39] revealed that substitution of RCA for NCA reduced tensile strength by up to 26.2%. Kathkhuda et al [40] discovered that splitting tensile strength of RAC is around 14.3% lower than that of NAC.

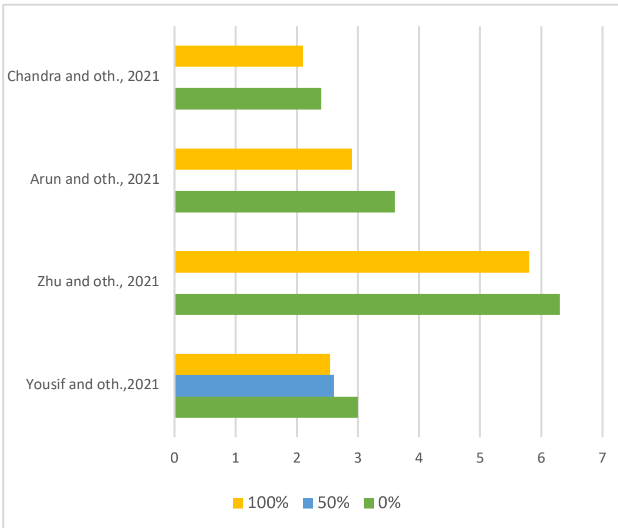

Fig. 5. Split Tensile strength of Recycled Aggregate Concrete by Various literatures.

4.6. Durability Performance of RAC

4.6.1. Chloride Ion Penetration

One of most frequent reasons of durability issues, notably in corrosion of structural concrete's reinforcing, is entry of chloride ions into concrete. In general, there are two ways that chloride ions can enter concrete: either by capillary suction and penetration of liquids containing chloride, or through diffusion of chloride ions through a saturated internal network of pores. Resistance of concrete against chloride penetration is negatively impacted by replacement of RCA from NCA and diminishes as degree of RCA replacement rises. It can be shown that adding fibre to concrete improves concrete's resistance to chloride infiltration. Introduction of supplementary cementitious material (SCM) reduces chloride ion penetration as 30% replacement of fly ash is most effective for chloride resistance, according to Sim and Park et al [41], who used fine RCA and stated that replacement level of fine RCA does not influence chloride ion penetration. According to N. Singh et al [42], total change of NCA with RCA resulted in a 34% increase in chloride penetration after 28 days of curing. Chloride ion penetration of all concrete mix combinations increased with an increase in the RCA content.

4.6.2. Water Absorption

Concrete durability may be evaluated indirectly by looking at water absorption. Most dangerous compounds are found in water, and when they interact with components of concrete, they alter concrete's characteristics. Concrete's pores may hold more water, which causes concrete to freeze and thaw as a result of temperature changes. Concrete experiences contraction and expansion, which reduces concrete's durability. Due to RCA's lesser ITZ, it can be observed that replacing it with NCA boosts concrete's ability to absorb water. Gonzalez Andreu et al [43] note in their investigation that despite having a lower water cement ratio than natural aggregate concrete, all recycled aggregate concrete did not absorb more water by capillary action.

It has been observed that adding fibres to concrete reduces amount of water it absorbs. In their study, Jawad Ahmad et al [25] discovered that nylon fibres increase concrete durability and decrease water absorption in concrete. He also claimed that too much fibre forms a cluster that causes microcracks, which causes concrete to absorb more water and become less durable.

Mix comprising 100 percent recycled concrete aggregate had maximum capillary water absorption at 28 days, following research by Chiranjiakumari and Ahmad, 2020 [44]. Water absorption does, however, decrease over time, peaking at 0.0254 mm/s 0.5 after 120 days of cure at 100% RCA content. 28 days after curing, when recycled concrete aggregate has replaced 50% of NCA, initial level of absorption values rise by around 12%.

5. Concluding Remark

According to report, recycled aggregate concrete for future construction projects has to be strong and produced using environmentally friendly methods. Usage of RAC with fibres will provide positive outcomes and recommend further use. Assessment's conclusion, which was discussed in this, is listed below.

1. Performance of fresh concrete, such as workability and air voids, will be impacted by use of RCA with fibre in concrete.
2. When RCA and fibre are used in concrete, concrete will perform well in terms of its compressive strength, flexural strength, and tensile strength.
3. When RAC and fibre are combined, it may be argued that concrete performs well in terms of its mechanical qualities.
4. Addition of fibre to RAC may increase concrete's resistance to chloride penetration.
5. Addition of fibre to RAC may decrease concrete's ability to absorb water, which increases its durability.
6. After fibre is added to concrete mix, durability performance of recycled aggregate concrete is improved.

Finally, use of RCA with fibre in concrete is advised and it could be a beneficial move for construction industry in direction of sustainable construction.

Acknowledgement

The information from many research studies served as foundation for data offered in this study. Authors would like to thank all the scholars working in this field.

References

[1] R.V. Silva, J. de Brito, R.K. Dhir, “Properties and composition of recycled aggregates from construction and demolition waste suitable for concrete production,” *Const Build Mat* Vol. 65, pp. 201–217, Aug. 2014, doi: https://doi.org/10.1016/j.conbuildmat.2014.04.117.

[2] D. Matias, J. de Brito, A. Rosa, P. d., “Mechanical properties of concrete produced with recycled coarse aggregates – Influence of the use of superplasticizers,” *Const Build Mat* Vol. 44, pp. 101–109, July 2013, doi: https://doi.org/10.1016/j.conbuildmat.2013.03.011.

[3] F.M.Z. Hossain, M. Shahjalal, K. Islam, M. Tiznobaik, M.S. Alam, “Mechanical properties of recycled aggregate concrete containing crumb rubber and polypropylene fiber,” *Const Build Mat*, Vol. 225, pp. 983–996, Nov. 2019, doi: https://doi.org/10.1016/j.conbuildmat.2019.07.245S.

[4] Binte Huda, M.Shahria Alam, “Mechanical behavior of three generations of 100% repeated recycled coarse aggregate concrete,” *Const Build Mat*, Vol. 65, pp. 574-582, Aug. 2014, doi: https://doi.org/10.1016/j.conbuildmat.2014.05.010.

[5] C. Zhou, Z. Chen, “Mechanical properties of recycled concrete made with different types of coarse aggregate,” *Const Build Mat* Vol. 134, pp. 497–506, March 2017, doi: http://dx.doi.org/10.1016/j.conbuildmat.2016.12.163.

[6] M. Shahria Alam, E. Slater, and A. H. M. Muntasir Billah, “Green Concrete Made with RCA and FRP Scrap Aggregate: Fresh and Hardened Properties,” *J. Mater. Civ. Eng.*, vol. 25, no. 12, pp. 1783–1794, Dec. 2013, doi: 10.1061/(ASCE)MT.1943-5533.0000742.

[7] M. C. Limbachiya, T. Leelawat, and R. K. Dhir, “Use of recycled concrete aggregate in high-strength concrete,” *Mat. Struct.*, vol. 33, no. 9, pp. 574–580, Nov. 2000, doi: 10.1007/BF02480538.

[8] C.F. Hendriks, H.S. Pieterson, *“Sustainable* raw materials—construction and demolition waste,” RILEM Report, RILEM Publication Series Vol.22, 2000, doi:https://www.rilem.net/publication/publication/86.

[9] BSI-BS 6543:1985*, “Guide to the use of industrial byproducts and waste materials in building and civil engineering,”* British Standards, Institution, London, 1985,

[10] D.M, *"New technical standard for civil construction,"* Italian Ministry of Infrastructure 2008.

[11] W.-C. Choi, H.-D. Yun, "Compressive behavior of reinforced concrete columns with recycled aggregate under uniaxial loading," *Eng Struct,* Vol. 41, pp. 285–293, Aug. 2012, doi: http://dx.doi.org/10.1016/j.engstruct.2012.03.037.

[12] J. Xiao, J. Li, C. Zhang, "Mechanical properties of recycled aggregate concrete under uniaxial loading," *Cem Conc Res*, Vol. 35 (6), pp. 1187–1194, June 2005, doi: https://doi.org/10.1016/j.cemconres.2004.09.020.

[13] Y. Zheng, X. Wu, G. He, Q. Shang, J. Xu, Y. Sun, "Mechanical Properties of Steel Fiber-Reinforced Concrete by Vibratory Mixing Technology*," Advances in Civil Engineering,* Vol. 11, pp. 1-11, July 2018, doi: http://dx.doi.org/10.1155/2018/9025715.

[14] J. Lee, T. Yuan, H. Shin, Y. Yoon, "Strategic use of steel fibers and stirrups on enhancing impact resistance of ultra-high-performance fiber-reinforced concrete beams," *Cem Conc Comps*, Vol. 107, pp. 103499, March 2020, doi: https://doi.org/10.1016/j.cemconcomp.2019.103499.

[15] V. Guerini, A. Conforti, G. Plizzari, S. Kawashima, "Influence of Steel and MacroSynthetic Fibers on Concrete Properties," *Fibers,* Vol. 6 (3), pp. 47, July 2018, doi: https://doi.org/10.3390/fib6030047.

[16] T. Uygunoglu, "Effect of fiber type and content on bleeding of steel fiber reinforced concrete," *Const Build Mat,* Vol. 25 (2), pp. 766–772, Feb. 2011, doi: http://dx.doi.org/10.1016/j.conbuildmat.2010.07.008.

[17] A.M. Alhozaimy, P. Soroushian, F. Mirza, "Mechanical properties of polypropylene fiber reinforced concrete and the effects of pozzolanic materials," *Cem Conc Comps*, Vol. 18 (2), pp. 85–92, 1996, doi: https://doi.org/10.1016/0958-9465(95)00003-8.

[18] H. Mazaheripour, S. Ghanbarpour, S.H. Mirmoradi, I. Hosseinpo ur, "The effect of polypropylene fibers on the properties of fresh and hardened lightweight self-compacting concrete," *Const Build Mat,* Vol. 25, pp. 351-358, Jan. 2011, doi: http://dx.doi.org/10.1016/j.conbuildmat.2010.06.018.

[19] C.R. Meesala, "Influence of different types of fiber on the properties of recycled aggregate concrete," *Structural Concrete,* Vol. 20 (5), pp. 1656–1669, July 2019, doi: https://doi.org/10.1002/suco.201900052.

[20] D. Gao, Z. Gu, Y. Pang, L. Yang, "Mechanical properties of recycled fine aggregate concrete incorporating different types of fibers*," Const Build Mat,* Vol. 298, pp. 123732, Sept. 2021, doi: https://doi.org/10.1016/j.conbuildmat.2021.123732.

[21] Sherif yehia, Karim Helal, Anaam Absharkh, AmaniZaher, and Hiba Istaitiyeh, "Strength and Durability Evaluation of Recycled Aggregate Concrete," *Concrete structure and Materials,* Vol.9, pp. 219-239, May 2015, doi:https://doi.org/10.1007/s40069-015-0100-0.

[22] M. Abed, R. Nemes, and B. A. Tayeh, "Properties of self-compacting high-strength concrete containing multiple use of recycled aggregate," *Journal of King Saud University - Engineering Sciences*, vol. 32, no. 2, pp. 108–114, Feb. 2020, doi: 10.1016/j.jksues.2018.12.002.

[23] Dehong wang, Yanzhong Ju, Hao Shen, and Libin Xu, "Mechanical properties of high performance concretereinforced with basalt fiber and polypropylene fiber," *Const Build Mat*, Vol. 197, pp. 464-473, Feb. 2019, doi: https://doi.org/10.1016/j.conbuildmat.2018.11.181.

[24] Chunsheng Zhang, Yanzhi Wang, Xianggang Zhang, Yahong Ding, and Ping Xu, "Mechanical Properties and microstructure of basalt fiber- reinforced recycled concrete," *Journal of Cleaner Production*, Vol.278, pp. 123252, Jan. 2021, doi: https://doi.org/10.1016/j.jclepro.2020.123252.

[25] Jawad Ahmad, Osama Zaid, Fahid Aslam, Rebeca Martinez Garcia, Yasir M. Alharthi, Mohammed Hechmi EI Ouni, Rana Faisal Tufail, and Ibrahim A. Sharaky, "Mechanical properties and durability assessment of nylon fiber reinforced self-compacting concrete," *Journal of Engineered Fiber and Fabrics,* Vol. 21, Dec. 2016, doi: https://doi.org/10.1177/15589250211062833.

[26] Jose A. Ortiz-Lozano, Francisco Mena-Sebastia, Ignacio Segura, Albert de la Fuente, Antonio Aguado, "Structural use of fiber-Reinforced self-compacting concrete with recycled aggregate: case study of a foundation wall in spain," *Case Studies in Construction Materials*, Vol. 17, pp.e01334, Dec. 2022 doi:https://doi.org/10.1016/j.cscm.2022.e01334.

[27] Mohammed Abed, Jan Fort, Khuram Rashid, "Multicriterial Cycle Assessment of eco-efficient self-compacting concrete modified by waste perlite powder and / or recycled concrete aggregate," *Const Build Mat,* Vol.343, pp. 128696, Aug. 2022, doi: http://dx.doi.org/10.1016/j.conbuildmat.2022.128696.

[28] Victor Revilla-Cuesta, Vanesa Ortega -Lopez, Flora Faleschini, Ana B. Espinosa, Roberto Serrano-Lopez, "Hammer Rebound index as an overall-mechanical quality indicator of self-compacting concrete containing recycled concrete aggregate," *Const Build Mat,* vol.347, pp. 128549, Sept. 2022, doi: https://doi.org/10.1016/j.conbuildmat.2022.128549.

[29] Md. Jahidul Islam, Kamrul Islam, Md. Shahjalal, Ehsani Khatun, Somaiya Islam, Anika Binte Razzaque, "Influence of difference types of fiber on the mechanical properties of recycled waste aggregate concrete," *Const Build Mat,* vol. 337, pp. 137577, June 2022, doi: https://doi.org/10.1016/j.conbuildmat.2022.127577.

[30] Xinglong Yao, Zhiyang Pei, Haoyuan Zheng, Qizhou Guan, Fupeng wang, Shuo wang, and Yongcheng Ji, "Review of mechanical properties of fiber reinforced recycled aggregate concrete," *Building Materials,* vol. 12(8), pp. 1224, Aug. 2022, doi:https://doi.org/10.3390/buildings12081224.

[31] Yuanxun Zheng, Jigbo Zhuo, Peng Zhang, "A review on Durability of nano-siO_2 and basalt fiber modified recycled aggregate concrete," *Const Build Mat,* vol. 304, pp. 124659, Oct. 202, doi: https://doi.org/10.1016/j.conbuildmat.2021.124659.

[32] Chandra Sekhar Das, Tanish Dey, Ramkrishna Dandapat, Bibhuti Bhusan Mukharjee, Jitendra Kumar, "Performance of Polypropylene fibre reinforced recycled aggregate concrete," *Const Build Mat,* vol 189, pp. 649-659, Nov. 2018, doi: https://doi.org/10.1016/j.conbuildmat.2018.09.036.

[33] A.K. Padmini, Dr. K. Ramamurthy, and Dr. M.S. Mathews, "Influence of parent concrete on the properties of recycled aggregate concrete," *Const Build Mat,* vol. 23, pp. 829-836, Feb. 2009, doi: https://doi.org/10.1016/j.conbuildmat.2008.03.006.

[34] Etxeberria M, Vázquez E, Marí A, Barra M., "Influence of amount of recycled coarse aggregates and production process on properties of recycled aggregate concrete," *Cem Conc Res,* vol. 37, pp. 735–42, May 200, doi: https://doi.org/10.1016/j.cemconres.2007.02.002.

[35] Poon CS, Shui ZH, Lam L, "Effect of microstructure of ITZ on compressive strength of concrete prepared with recycled aggregates," *Constr Build Mater,* vol. 18, pp. 461–468, July 2004, doi: https://doi.org/10.1016/j.conbuildmat.2004.03.005.

[36] Etxeberria M, Vázquez E, Marí AR, "Microstructure analysis of hardened recycled aggregate concrete," *Mag Concr Res*, Vol. 58, no 10, pp. 683–690, Dec. 2006, doi: https://doi.org/10.1680/macr.2006.58.10.683.

[37] Sriram, M. Sidhaarth, K.A, "Various properties of natural and artificial fibers with cementitious composites in hybrid form – A review," *Mater Tod Proc*, vol. 60, pp. 2018-2025, 2022, doi: https://doi.org/10.1016/j.matpr.2022.01.266.

[38] Sivakumar, A. Santhanam, M.A, "Quantitative study on the plastic shrinkage and cracking in high strength hybrid fibre reinforced concrete," *Cem Conc Comp,* vol. 29, pp. 575-581, Aug. 2007, doi: https://doi.org/10.1016/j.cemconcomp.2007.03.005.

[39] Dimitriou G, Savva P, Petrou M.F, "Enhancing the mechanical and durability properties of recycled aggregate concrete," *Const Build Mat,* vol. 158, pp. 228-235, Jan. 2018, doi: https://doi.org/10.1016/j.conbuildmat.2017.09.137.

[40] Kathkhuda, H; Shatrat, N, "Improving the mechanical properties of recycled concrete aggregate using chopped basalt fibers and acid treatment*," Constr Build Mat,* vol. 140, pp. 328-335, June 2017, doi: https://doi.org/10.1016/j.conbuildmat.2017.02.128.

[41] J. Sim, C. Park, "Compressive strength and resistance to chloride ion penetration and carbonation of recycled aggregate concrete with varying amount of fly ash and fine recycled aggregate," *W Manag,* vol. 31, pp. 2352–2360, July 2011, doi: https://doi.org/10.1016/j.wasman.2011.06.014.

[42] N. Singh, M. M, S. Arya, "Utilization of coal bottom ash in recycled concrete aggregates based self compacting concrete blended with metakaolin," *R, Conserv Rec*, vol. 144, pp. 240–251, May 2019, doi: https://doi.org/10.1016/j.resconrec.2019.01.044.

[43] Gonzalez Andreu, Etxeberria Miren, "Experimental analyais of properties of high performance recycled aggregate concrete," *Const Build Mat,* vol.52, pp. 227-235, Feb. 2014, doi: https://doi.org/10.1016/j.conbuildmat.2013.11.054.

[44] S. Chiranjiakumari Devi, R.Ahmad Khan, "Compressive strength and durability behavior of graphene oxide reinforced concrete composites containing recycled concrete aggregate," *J Build Engin* vol.32, pp. 101800, Nov. 2020, doi: https://doi.org/10.1016/j.jobe.2020.101800.