Analysis on Characteristics of Self Compacting Concrete Using Recycled Aggregate: A Review

Swapna Rani Pradhan¹, Priyanshu Sinha ², Sudipta Hui ³ and Gaurav Udgata ⁴

¹,²,³ Post Graduate Student, School of Civil Engineering, KIIT Deemed To Be University, Bhubaneswar, India
⁴ Associate Professor, School of Civil Engineering, KIIT Deemed To Be University, Bhubaneswar, India

Abstract: The inclusion of SCC or self-consolidating concrete is an innovative way to capitalize on the demolished coarse aggregates in concrete. This can be obtained by crushing of old concrete specimens, beams, slabs, etc. This methodology was first introduced in Japan due to the scarcity and unavailability of labor. Since then it has gained popularity and has become a trend in the construction sector. Its characteristics and properties are more or less similar to that of conventional concrete. The flowability is good and there is no segregation of materials. It eliminates the vibration or any sort of compaction method which makes it easier to operate and perform in situ. The durable property offers rehabilitation such as repair applications. In this work SCC along with Recycled Coarse Aggregate (RCA) is used in various proportions. The results are obtained and compared for determining the best proportion that can be adopted for practice. SCC, when incorporated with Recycled Aggregate (RA), showed a drop in compressive strength at various curing periods. Apart from mechanical properties, other various factors are discussed such as durability and microscopic analysis. This will help in understanding its scope in the future.

Keywords: Self-Compacting Concrete, Recycled Coarse Aggregate, Natural Coarse Aggregate.

I. Introduction

Concrete mainly comprises cement, aggregates, and water. Each of the materials imparts different properties to the concrete. Aggregates occupy 70-80% of concrete volume. The primary function of aggregate is to suffice the strength of concrete. In this paper, RA is used in place of natural aggregate (NA). RA is obtained from the demolition of concrete. This is classified into two types, namely recycled coarse aggregate (RCA) and recycled fine aggregates (RFA). Around 40 billion tonnes of aggregates are produced annually throughout the globe. The production of these aggregates causes pollution in the atmosphere. By research, it was found that the aggregates can be reused in concrete. It has several advantages over NA. It makes the concrete more durable it serves better resistance against carbonation, freeze-thaw effect, etc.

It’s quite evident that SCC has an edge over normal concrete (NC). It offers better flowability that spreads uniformly without any application of vibration. The action of compaction of concrete is done by its weight, thereby maintaining durability and performance. It offers high workability and has low viscosity due to fines content. It also gives an aesthetic finish to the concrete. This review paper highlights the advantages and feasibility of SCC-RA. This depends upon the ratio of the replacement of aggregates. It makes the concrete more durable as it shows better resistance to Rapid Chloride Penetration test (RCPT), freeze-thaw effect, carbonation, etc. It gives an aesthetic finish. Despite several advantages, it requires further investigation in depth.

II. Literature Review

This section deals with the literature of various authors and their work. It comprises of mechanical properties, durability, fresh properties and microstructural study.

2.1 Mechanical Properties

(Omrane & Rabehi, 2020) investigated and quoted that the mechanical characteristics of concrete having pozzolan are almost similar to that of concrete without natural pozzolan. It adds an edge in the capillary part of a paste of the cement. UPV of RSCC with natural pozzolan reduces with an increment in the aspect of the same. Due to RA, the formations of the natural SCC are lower that of RSCC at all stages[1].

(Pan et al., 2019) established that the infilling and passing of SCC increased with the replacement ratio of SSP, whereas the resistance curing period showed significant to segregation gets reduced. The prior strength of SCC in collaboration with RA & SSP was slow. But in the long run, the curing showed significant improvement. For the substitution ratio of SSP increased is over 20%, the strength of SCC with RA gets decreased. Whereas a 10% replacement of OPC showed maximum compressive strength. It also achieved superior splitting tensile strength[2].
researched and concluded that the inclusion of RCA leads to a decrease in the mechanical characteristics of concrete. It slightly decreases the modulus of elasticity. Despite the reduction, it did not affect the potential as structural concrete in terms of mechanical strength. It was noted that RCA can be used as structural SCAs the criteria for strength satisfaction[3].

(Salesa et al., 2017) studied and stated that the water absorption of the concrete specimen made of RA increases its bulk density but is less of NA. Due to the use of repeated RA showed better mechanical strength at 28 days. Due to the superior quality of RA, there is a modification in the compressive strength of concrete [4].

(Kou & Poon, 2009) There is a decline of compressive as well as the tensile strength of SCC containing RA without FA with an increment of RA content. The most optimum results are attained when 25-50% RFA is substituted by river sand [5].

(Panda & Bal, 2013) concluded that the inclusion of RCA reduces the strength parameter of SCC when compared to NVC. After performing the test of compressive strength, it was observed that it slightly attains the required strength up to 0.3 substitution ratio. The maximum flexural strength was attained which has 100% NCA NVC. At 28 days. The value of flexural strength of SCC is less of given conceptual flexural strength by all substitution of RFA. It absorbs more water than NCA which has lower specific gravity [6].

(Ardalan et al., 2020) While experimental work it was noticed that the viscosity of polymeric concrete gets reduced in comparison with control concrete. SCC with NA showed twice compressive strength in comparison to RCA and polymeric concrete. Whereas polymeric SCC showed compressive strength half of SCC which is of control mix. The most optimum quantity of polymer is 15% which enhances the workability and keeps the flexural strength [7].

(Khodair & Luqman, 2017) through investigation quoted that better strength, frugal, along with workability and durability of SCC can be attained by adding FA 70% and Slag 70% in concrete as partial substitution of OPC. The compressive & split tensile strength of the SCC specimen gets reduced. When NCA is replaced by RCARP y 25%, 50% & 75% [8].

(Panda & Bal, 2013) examined and quoted that the mechanical strength of SCC comprising of RCA enhances the dosage as it offers a higher rate of water absorption which minimizes the W/C which increases its strength. On keeping W/C constant the sample with a greater proportion of replacement of RCA offers higher compressive strength. The rate of penetration of water with replacement is lower. For 0.45, the values lie from 3 to 8 mm. Whereas for conventional it is 6mm for 0.55 and 25mm for 0.50 [9].

(Alaptopitiya & Labana, 2015) researched and found that increment of CRCA & FRCA decreases the compressive strength of the SCC mix. But the inclusion of SF contributes to enhancing the compressive strength but still does not gives the required strength [10].

(Guo et al., 2020) investigated and stated that the inclusion of RCA in the concrete mixture reduces the mechanical properties and its aspects. 20% of RA-SCC, 20% FA, and SL, 10% of SF, or 30% of FA showed results comparable with the control mix [11].

(Mahakavi & Chithra, 2019) concluded that the mechanical strength of the specimen reduces linearly with an increment % of RCA. The entire substitution of RCA with NCA minimizes brings down its strength to 50%. The substitution of NFA with M-sand modified the mechanical strength. It increases up to 50% substitution. Other tests such as spilled tensile & flexural strength depend upon the replacement of RCA as it reduces. The replacement of NFA enhances the split tensile strength [12].

(Singh et al., 2019) investigated and concluded the deviation in the compressive strength of SCRAC in comparison to concrete made with NA with the same W/C ratio [13].

(Nuralinah et al., 2019) researched and concluded that the concrete made up of NA offers higher compressive strength that of concrete with SCC. The Young’s modulus of both SCC and NC correspond with compressive strength. The mean is evaluated based on the SNI & ACI standard [14].

(Carro-López et al., 2015) stated that the use of RFA of 100% affected the compressive strength of mortar when cured for a period of 28 days. For 100% replacement, it was 49%, whereas for 20% replacement it was by 9% [15].

2.2 Durability

(Omrane & Rabehi, 2020) Both control concrete & natural SCC has higher thermal conductivity compared to other with natural pozzolan [1].

(Francisco et al., 2013) It also enhances the durability in terms of chloride penetration & carbonation[2].

(Pereira-De-Oliveira et al., 2014) the inclusion of RCA requires more amount of superplasticizer concerning the fresh concrete properties. Approximately it is 2% of the total NCA replacement. This is due to the water fraction that is concerned, there is an alight weight loss. The compressive strength decreases by 3.3% when the maximum RCA is used. The dynamic modulus of elasticity is reduced by 8% when compared to NCA SCC[16].

(Kou & Poon, 2009) It showed resistance against RCPT [5].
(Khidair & Luqman, 2017) SCC containing SCMs provides superior resistance to RCPT [8].

(Nieto et al., 2019) In terms of durability, lower W/C offers lower carbonation and better durability [9].

(Kapoor et al., 2018) SF significantly reduces RCPT in SCC. By replacing OPC by 10% SF and substituting all NA with CRCA & FRCA, it was observed that RCPT is slightly less than of CC [10].

(Guo et al., 2020) Thawing resistance depends upon RCA content. 25% of RA-SCC replacement with higher volumes exhibits the best properties and performance in terms of durability. Dry shrinkage increases with an increment of RCA percentage [11].

(Singh & Singh, 2018) researched and stated that an increase of RFA and RCA reduces the resistance to carbonation. When 100% of RCA & RFA is replaced, the depth of carbonation reaches 70% in comparison to NC after 28 days. The strength of SCC comprising of RFA is lesser than that of NC. The loss gets compensated when MK is used in SCC having RFA. When both RCA and RFA are replaced, a huge drop in compressive strength is observed. The inclusion of MK serves resistance to carbonation. 50% replacement of NCA and NFA with RCA and RFA showed gives the best results. The depth of carbonation is inversely proportional to the curing ages. The long duration of curing increases the resistance to carbonation of SCC containing RCA & RFA [17].

### 2.3 Fresh Properties of Concrete

(Gradic et al., 2010) researched and stated that it is quite imperative to know the RA as the superior quality gives better performance to the concrete. The RA exhibits more water absorption as compared to NA due to powdered cement. Therefore, more amount of water is required. For 50-100% of RCA, the water absorption from 0.15-0.37%. Maximizing the percentage of RA in concrete results in declination of its density as porosity increases. It has been observed that by replacing 50% of RCA decreases the density by 2.12%, whereas for 100% by 3.40%. The inclusion of RCA in concrete has a direct influence on concrete. The tensile strength falls from 2.49-13.95%. The SCC with RA is proved to be waterproof. This parameter is associated with the capillary pores formed in residual of old and new aggregate. By adopting an adequate kind of material and mix design, HPC can be obtained by incorporating RA for making SCC [18].

(Kou & Poon, 2009) investigated and found that both RCA & RFA can be entertained in SCC work. The blocking ratio & slump flow of the RA-SCC mix is directly proportional to RFA. Initially, the minimum measured slump flow of the mix was 760 mm whereas blocking ratios range from (0.85-0.94). With the inclusion of FA, the flow of slump is better. Whereas the blocking ratio gets benefited [5].

(Abed et al., 2020) evaluated that the amount of chemical admixtures used in RAC & RRAC lies in the identical standard of fresh properties is same. 50% substitution of NA with RCA is considered the most optimum substitution. The utilization of RRCA is said to be the first initiative for slightly using aggregates as a sustainable resource. SCHSC is considered to be the best option for reusing RCA & RRCA. By performing the CT test, it was observed that the inclusion of RRCA reduces pore volume in comparison to RCA [19].

(Rajhans et al., 2019) stated that the properties of concrete get enhanced when RCA is involved with SS and SF as it fills the pores and cracks [20].

(Ardalan et al., 2020) researched and stated that there is an increment of workability of SCC when a polymer is used. It enhances the free flow while performing slump tests and reduces the motion of water and fine particles are drag apart from concrete while ahomogeneity is maintained. The inclusion of the polymer reduces the flow duration of SCC. It was noticed that capability of filling concrete by four times. When compared to control concrete, the SCC with polymer showed significant improvement in the L-box & J-ring test of 100% over 80%. While experimental work it was noticed that the viscosity of polyme concrete gets reduced in comparison with control concrete [7].

(Fiol et al., 2018) investigated and concluded that the RA originated from precast specimens is proved to be a better-quality aggregate. The inclusion of RA minimizes the W/C which gets compensated by utilizing superplasticizer admixtures for attaining the right slump flow. Because of the greater water absorption coefficient by RA, the slump obtained gets decreased despite increasing superplasticizer. The substitution of NA decreases the density of concrete. Whereas both water absorption & porosity increases [21].

(Güneyisi et al., 2016) researched and concluded that the density of fresh concrete declines when there is an increment of FRCA as the RCA offers lower specific gravity than NA. Because of the much high angular shape of CRCA flowability gets decreased when 50% of CRCA is replaced in the concrete. Whereas the slump flow increases. Replacement by CRCA for 50% offers a high L-box height ratio, whereas for 100% it is lower [22].

(Khidair & Luqman, 2017) When NCA is replaced by RCARP by 25%, 50% & 75%. Workability gets reduced. Whereas the shrinkage increases. SCC containing SCMs provides superior resistance against RCPT [8].
(Singh et al., 2019) The inclusion of RA offers modified inter bonding and good interlocking of aggregates. The density of concrete comprising of RA depends on its origin. In comparison to SCNAC, SCRAC possesses more shrinkage. SCRAC offers less thermal conductivity[13].

(Manzi et al., 2017) researched and quoted that approximately 40% replacement of RCA in the mix gives the most feasible results. Because of the modification of microstructure, the physical characteristics of SCC containing RA are equivalent to NC with NA. SCC containing RA is more susceptible to creep rather than shrinkage. SCC with RA affects the porosity[23].

(Carro-López et al., 2015) By increasing the ratio of replacement, the flowability of SCCRA gets reduced. The mix comprising of 50% & 100% of FRA entirely lost the characteristics of SCC at 90 min. The slump flow also gets reduced at a lower rate for less substitution of natural sand. From 0% & 20% it indicated similar behaviour. Whereas from 50% & 100% the SCC loses its characteristics. The L-Box test showed that replacement of 0 and 20% indicated familiar results [15].

2.4 Microstructural

(Abed et al., 2020) By performing the CT test, it was observed that the inclusion of RRCA reduces pore volume in comparison to RCA [19].

(Rajhans et al., 2019) stated that the properties of concrete get enhanced when RCA is involved with SS and SF as it fills the pores and cracks [20].

III. Research Gaps, Status And Future Trends

The inclusion of RA in SCC results in a decrease of compressive and flexural strength. This indicates that the mixture requires some research work to overcome this issue. The use of steel fibers may offer a good impact as it encounters the loss of strength. Therefore the investigation is to be done in-depth.

Currently, the trend of using SCC-RA holds a good future. It not only makes the concrete durable but also enhances workability. The use of superplasticizer increases the bond between the aggregate and cement matrix. Due to low fines content, the viscosity is low. It has an edge for thick reinforcement works.

The use of SCC-RA has a scope in the future. But there are certain mandatory steps to be taken during the process such as the use of superplasticizer in terms of quality and quantity. The quality depends upon the ratio of replacement and its origin. But still, some investigation is required before practicing.

IV. Discussion

The use of RA resolves the issue of dumping hundreds of thousands of tons of demolition wastes. The use of RA in SCC has its pros and cons. The mechanical strength decreases to some extent due to used aggregates, but it maintains the target strength depending upon replacement done. It also showed better resistance to RCPT, carbonation, and freeze-thaw effect.

V. Conclusion

It’s quite evident that the incorporation of RA in the concrete adds certain advantages to its properties. Some of them are listed below:

1. The inclusion of RCA in concrete decreases its mechanical strength and modulus of elasticity.
2. Replacement of 50% of RCA decreases the density by 2.12%, whereas for 100% by 3.40%. The inclusion of RCA in concrete has a direct influence. The tensile strength falls from 2.49-13.95%.
3. RCA absorbs more water in comparison to NA.
4. The use of crushed concrete aggregate reduces carbon footprint.
5. The properties of concrete get modified when RCA is used with sodium silicate and silica fume as it fills the pores and cracks.
6. Activation energy increases for a mix containing RA over 20%. Whereas for 8%, it shows less activity.

References


NCACME 2020 "Girijabai Sail Institute of Technology, Karwar, Karnataka 581345 31 | Page


