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

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Abstract*: The inclusion of SCC or self-consolidating concrete is an innovative way to capitalize onthe demolished coarse aggregates in concrete. This can be obtained by crushing of old concretespecimens, beams, slabs, etc. This methodology was first introduced in Japan due to the scarcity andunavailability of labor. Since then it has gain popularity and has become a trend in the constructionsector. Its characteristics and properties are more or less similar to that of conventional concrete. Theflowability is good and there is no segregation of materials. It eliminates the vibration or any sort ofcompaction method which makes it easier to operate and perform in SITU. The durable propertyoffers rehabilitation such as repair applications. In this work SCC along with Recycled CoarseAggregate (RCA) is used in various proportions. The results are obtained and compared fordetermining the best proportion that can be adopted for practice. SCC, when incorporated withRecycled Aggregate (RA), showed a drop in compressive strength at various curing periods. Apartfrom mechanical properties, other various factors are discussed such as durability and microscopicanalysis. 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 impartsdifferent properties to the concrete. Aggregates occupy 70-80% of concrete volume. Theprimary function of aggregate is to suffice the strength of concrete. In this paper, RA is usedin place of natural aggregate (NA). RA is obtained from the demolition of concrete. This isclassified into two types, namely recycled coarse aggregate (RCA) and recycled fineaggregates (RFA). Around 40 billion tonnes of aggregates are produced annually throughoutthe globe. The production of these aggregates causes pollution in the atmosphere. Byresearch, it was found that the aggregates can be reused in concrete. It has several advantagesover 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 betterflowability that spreads uniformly without any application of vibration. The action ofcompaction of concrete is done by its weight, thereby maintaining durability andperformance. It offers high workability and has low viscosity due to fines content. It alsogives an aesthetic finish to the concrete. This review paper highlights the advantages andfeasibility of SCC-RA. This depends upon the ratio of the replacement of aggregates. It makesthe 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 severaladvantages, it requires further investigation in depth.

II. Literature Review

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

2.1 Mechanical Properties

(Omrane & Rabehi, 2020)investigated and quoted that the mechanical characteristics ofconcrete having pozzolan are almost similar to that of concrete without natural pozzolan. Itadds an edge in the capillary part of a paste of the cement. UPV of RSCC with naturalpozzolan reduces with an increment in the aspect of the same. Due to RA, the formations ofthe 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 thereplacement ratio of SSP. whereas the resistance curing period showed significant tosegregation gets reduced. The prior strength of SCC in collaboration with RA & SSP waslow. But in the long run, the curing showed significant improvement. For the substitutionratio of SSP increased is over 20%, the strength of SCC with RA gets decreased. Whereas a10% replacement of OPC showed maximum compressive strength. It also achieved superiorsplitting tensile strength[2].

(Mohammed & Najim, 2020)researched and concluded that the inclusion of RCAleads to a decrease in the mechanical characteristics of concrete. It slightly decreases themodulus of elasticity. Despite the reduction, it did not affect the potential as structuralconcrete 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 specimenmade RA increases its bulk density but is less of NA. Due to the use of repeated RA showedbetter mechanical strength at 28 days. Due to the superior quality of RA, there is amodification in the compressive strength of concrete [4].

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

(Panda & Bal, 2013)concluded that the inclusion of RCA reduces the strengthparameter 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. Themaximum flexural strength was attained which has 100% NCA NVC. At 28 days. The valueof flexural strength of SCC is less of given conceptual flexural strength by all substitution ofRCA. 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 ofpolymeric concrete gets reduced in comparison with control concrete. SCC with NA showedtwice compressive strength in comparison to RCA with control 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 theflexural strength [7].

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

(Nieto et al., 2019)examined and quoted that the mechanical strength of SCC comprisingof RCA enhances the dosage as it offers a higher rate of water absorption which minimizesthe W/C which increases its strength. On keeping W/C constant the sample with a greaterproportion of replacement of RCA offers higher compressive strength. The rate of penetrationof water with replacement is lower. For 0.45, the values lie from 3 to 8 mm. Whereas forconventional it is 6mm for 0.55 and 25mm for 0.50 [9].

(Kapoor et al., 2018)researched and found that increment of CRCA & FRCA decreasesthe compressive strength of the SCC mix. But the inclusion of SF contributes to enhancing thecompressive 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 mixreduces the mechanical properties and its aspects. 20% of RA-SCC, 20% FA, and SL, 10% ofSF, or 30% of FA showed results comparable with the control mix [11].

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

(Singh et al., 2019)investigated and concluded the deviation in the compressive strengthof 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 NCA offershigher compressive strength that of concrete with SCC. The Young's modulus of both SCCand 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 compressivestrength 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].

(Pan et al., 2019) 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].

(Khodair & Luqman, 2017) SCC containing SCMs provides superior resistance tom 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 Propertiesof Concrete

(Grdic et al., 2010)researched and stated that it is quite imperative to know the RA as thesuperior quality gives better performance to the concrete. The RA exhibits more waterabsorption as compared to NA due to powdered cement. Therefore, more amount of water isrequired. For 50-100% of RCA enhances the water absorption from 0.15-0.37%. Maximizingthe percentage of RA in concrete results in declination of its density as porosity increases. Ithas been observed that by replacing 50% of RCA decreases the density by 2.12%, whereas for100% by 3.40%. the inclusion of RCA in concrete has a direct influence on concrete. Thetensile strength falls from 2.49-13.95%. The SCC with RA is proved to be waterproof. Thisparameter 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 byincorporating RA for making SCC [18].

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

(Abed et al., 2020)evaluated that the amount of chemical admixture used in RAC &RRAC lies in the identical standard of fresh properties is same. 50% substitution of NA withRCA is considered the most optimum substitution. The utilization of RRCA is said to be thefirst initiation for slightly using aggregates as a sustainable resource. SCHSC is considered tobe the best option for reusing RCA & RRCA. By performing the CT test, it was observed thatthe 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 isinvolved 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 ofSCC when a polymer is used. It enhances the free flow while performing slump tests andreduces 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. Itwas noticed that capability of filling concrete by four times. When compared to controlconcrete, the SCC with polymer showed significant improvement in the L-box & J-ring test of100% over 80%. While experimental work it was noticed that the viscosity of polymericconcrete gets reduced in comparison with control concrete[7].

(Fiol et al., 2018)investigated and concluded that the RA originated from precastspecimens is proved to a better-quality aggregate. The inclusion of RA minimizes the W/Cwhich gets compensated by utilizing superplasticizer admixtures for attaining the right slumpflow. Because of the greater water absorption coefficient by RA, the slum obtained getsdecreased despite increasing superplasticizer. The substitution of NA decreases the density ofconcrete. Whereas both water absorption & porosity increases[21].

(Güneyisi et al., 2016)researched and concluded that the density of fresh concrete declineswhen 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% ofCRCA is replaced in the concrete. Whereas the slump flow increases. Replacement by CRCAfor 50% offers a high L-box height ratio, whereas for 100% it is lower[22].

(Khodair & Luqman, 2017) When NCA is replaced by RCARP by 25%, 50% & 75%.Workability gets reduced. Whereas the shrinkage increases. SCC containing SCMs providessuperior resistance against RCPT[8].

(Singh et al., 2019)The inclusion of RA offer modified inter bonding and goodinterlocking of aggregates. The density of concrete comprising of RA depends on its origin. Incomparison to SCNAC, SCRAC possesses more shrinkage. SCRAC offers less thermalconductivity[13].

(Manzi et al., 2017)researched and quoted that approximately 40% replacement of RCAin the mix gives the most feasible results. Because of the modification of microstructure, thephysical characteristics of SCC containing RA are equivalent to NC with NA. SCC containingRA 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 characteristicsof SCC at 90 min. The slump flow also gets reduced at a lower rate for less substitution ofnatural sand. From 0% & 20% it indicated similar behaviour. Whereas from 50% & 100% theSCC loses its characteristics. The L-Box test showed that replacement of 0 and 20% indicatedfamiliar 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 the indicates that it requires some research work to overcome this issue. The use of steel fibers may have 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.

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