

# Study on Fresh and Hardened Properties of Self Compacted Concrete Using Recycled Concrete Aggregate

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**ABSTRACT:** Self compacted concrete is a innovative concrete that does not required any vibration or compaction for placing. It is able to flow under its own weight even in the presence of congested reinforcement. Mix Design was carried out for M30 grade concrete as per the Guidelines of EFNARC. This paper presents an experimental investigation on strength aspects like compressive and split tensile strength of self-compacting concrete using recycled concrete aggregate and workability tests like (slump, L-box, J-ring, V-funnel and V-funnel T50) are carried out. In this study water to powder ratio is kept constant at 0.33. In this study, Natural aggregate is partially replaced with Recycled concrete aggregate by 10%, 20%, 30%, and 40% and Fly are replaced 25% for all mix for reducing the cost. To reduce the water absorption of recycled concrete aggregate, RCA submerged in water for 24 hours and used after saturated surface dry condition. The results of present study recommend SCC marginally achieves required compressive strength up to 30% replacement of Recycled concrete aggregate.

**KEYWORDS:** Natural aggregate (NCA), Recycled concrete aggregates (RCA), compressive strength, Split tensile strength, Self compacted concrete (SCC), fly ash.

## I. INTRODUCTION

Concrete is a widely used construction material all around the world, and its properties have been undergoing changes through technological advancement. Different types of concrete are available for different types of requirements. Some concrete are special type and some are standard type of concrete. Now a days, demand of concrete increases day by day because of fast population growth and a higher demand for housing and infrastructure. Recent development in civil engineering demands high rise building and long spans bridges. for the fulfillment of these demand high strength concrete is required .At the beginning by reducing the water–cement ratio is easiest way to achieved higher compressive strength. Compacting procedures applied to the structure role in gaining the initial as well as the ultimate strength of the structure.

To get higher strength and minimize the problem of compaction, During the 1990s, Professor Okamura and his PhD student Kazama Ozawa , Japan developed a concrete called Self Compacting Concrete (SCC) It's able to flow by it's own weight even in the congested reinforcement. SCC has three requirements passing. Filling and segregation ability The unique characteristics of SCC are a rapid rate of concrete placement with very less time. SCC provides good surface finishing and higher durability also SCC provides uniform strength and minimum void space in concrete. Several building applications, many in high volumes, show it can be prescribed and used as a reliable product in mass applications with confidence in supply and casting. In recent years self compacted concrete is more and more popular as ready mixed concrete and pre fabricated work in European country and Japan. There are no standard guidelines or criteria for making self compacted concrete so during 1989 European countries founded European federation of natural trade association representing producers and applicators of specialist building products (EFNARC)[4].

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Recycle concrete aggregate is a one type of natural aggregate but it's usable kind of aggregate. RCA are produced from the reprocessing of construction waste. The demand of natural aggregate is 48.3 billion metric tons in the year of 2015 with highest consumption in Asia and Pacific (the Fredonia group 2012). So for the fulfillment of demand recycled concrete aggregate is very important material and by utilizing RCA is certainly an important step towards sustainable development in the concrete industry and management of construction waste. The quality and properties of RCA depends on type of aggregate used in existing structure, existing structure strength, demolished method. RCA have lower density and specific gravity than natural aggregate and also they have higher water absorption value than natural aggregate value. Because of this properties of RCA proper mix design is required for obtaining the desired strength and workability of concrete. Some of the literature review of latest study using RCA are as follows [12] studies three series of SCC mixtures were prepared with 0, 25, 50, 75 and 100% fine recycled aggregates, the corresponding water-to-binder ratios (W/B) were 0.53 and 0.44 for the SCC mixtures in Series I and II, respectively. The SCC mixtures in Series III were prepared with 100% recycled concrete aggregates (both coarse and fine) but three different W/B ratios of 0.44, 0.40 and 0.35 were used. The results indicate that the properties of the SCCs made from river sand and crushed fine recycled aggregates showed only slight differences. [11] Four series of SCC mixtures were prepared with maximum of 30% of coarse recycled aggregates. The cement content was kept constant for all concrete mixtures. The SCC mixtures were prepared with 0, 10, 20 & 30% of recycled coarse aggregate. Four concrete mixes namely MCRR 0.0, MCRR 0.10, MCRR 0.20, and MCRR 0.30 were used. There is an improvement in the strength of self compacting concrete by using recycled coarse aggregate, maximum of 30% is better than concrete with natural aggregates [16] studies the replacement of RCA to natural aggregate up to 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%. It has been concluded that the flexural strength between 5.16.0Mpa; with recycled coarse aggregate replacement percentage increasing, the flexural strength tends to increase first and then decrease, while cubic compressive strength changes little.

The primary objective of the study is to evaluate different properties of SCC including fresh and hardened properties. Objectives of project work also includes the effect of using fly ash as an addition to SCC and study the compatibility of using recycled coarse aggregates in SCC. The main objective of this study is utilizing the recycled concrete aggregate as a replacement of natural aggregate in fresh and hardened properties of SCC.

## II. MATERIAL USED AND IT'S PROPERTIES

### A. Cement

Ordinary portland cement (OPC) (high bond) of 53 grade cement used confirming to IS 1489.

### B. Coarse Aggregate

Crushed coarse aggregate of maximum size 20 mm is used as per IS: 2386-1963. In this study there are two sizes of aggregate 16 mm and 10 mm were used with the proportion of 60 and 40 mm ratio. Coarse aggregate plays important role during making of SCC. Rounded or angular coarse aggregate are preferable for the fresh properties of SCC. More flaky and elongated aggregate can cause the blockage.

### C. Fine Aggregate

All normal concreting sands are suitable for SCC. Both crushed and rounded sands can be used. Siliceous or calcareous sands can be used. The amount of fines less than 0.125 mm is to be considered as powder and is very important for the rheology of the SCC. A minimum amount of fines (arising from the binders and the sand) must be achieved to avoid segregation.

### D. Mineral Admixtures

Locally available fly ash used (Gandhinagar thermal power plant). Fly ash in required quantity may improve the quality and durability of SCC.

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### E. Chemical Admixture

The new generation super plasticizer termed polycarboxylate ether is particularly useful for SCC. In this study high range super plasticizer master glanium sky 8784 which is the product of BASF Company were used.

### F. Mixing Water

The potable water can be used.

**Table 1: Physical properties of ordinary portland cement**

Characteristics	Value
Normal consistency, percent	30
Final setting time, minutes	30
Final setting time, minutes	600
3 days compressive strength MPa	37
7 days compressive strength MPa	47
28 days compressive strength MPa	53

**Table 2: Properties of aggregate**

Characteristics	Fine Aggregate	Coarse Aggregate	Recycled Concrete Aggregate
Specific gravity	2.75	2.75	2.42
Fineness modulus	6.15	6.15	6.10
Water absorption(%)	0.34	0.34	1.25

### G. Mix Proportions

The control mix with 100% natural aggregate for 30 grade concrete(without RCA) were are designed as per the guidelines of EFNARC with W/C=0.33 after that RCA are partially replaced by an amount 10%,20%,30% and 40%. In all these mix fly ash are kept constant 25 % replacement (by weight) of cement just for reducing the cost of SCC.. Slump flow, T500, V-funnel, v-funnel T5 min and L-Box tests were conducted for all mix proportion of SCC. The results were satisfied with the EFNARC 2005 guidelines. Crushed granite stones of size 10mm and 126 mm are used with the blending 60:40 by percentage weight of total coarse aggregate.

**(Control Mix) M0= CEMENT + FLY ASH (25%) + F.A. + C.A (100%) + WATER + S.P**

**Table 3: Work Plan**

Trial Mix	Recycled aggregate	Compressive strength(Days)		Split tensile strength(days)		Total number of cube	Total number of cylinder	
		7	28	7	28			
M1	10%	3	3	3	3	6	6	
M2	20%	3	3	3	3	6	6	
M3	30%	3	3	3	3	6	6	
M4	40%	3	3	3	3	6	6	
<b>Total specimen</b>							<b>48 Nos</b>	

**Total casting = 12+48= 60 Nos**

After the 10 trial, the mix design of SCC using natural aggregate are finalized and keep water- powder ratio keep constant 0.33. With the same proportion of SCC using natural aggregate it's not possible to achieved

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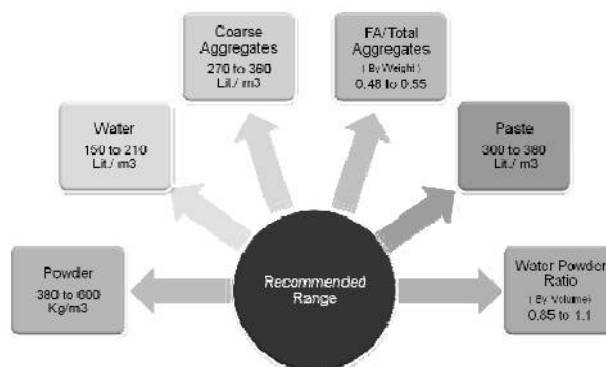
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40% replacement of recycled aggregate to natural aggregate because of properties of recycled aggregate is lower than natural aggregate. RCA have more water absorption properties than natural aggregate so by increasing super plasticizer and water finally got the workability as per the EFNARC guidelines.

### H. Mix Design Rules

There are no mix design rules for making the SCC so for finalized the mix proportion of SCC followed the rules as below which specified by EFNARC [1].



**Fig 1 Mix Design Rules**

### I. Troubleshooting

After successful laboratory & field trials, the SCC may be used for actual field application. It is observed that, while using the SCC in field, one may face issues during application due to various reasons. The table given below suggests the modification in the mix for troubleshooting.

Table 4 troubleshooting [1]

Test	Possible Cause	Effect	Remedy
Slump Flow on lower side than specified range	Viscosity too high	Blockage	↑ Water Content
			↑ SP
			↓ VMA
V Funnel Results on lower side than specified range	Viscosity too low	Segregation	↓ Water Content
			↓ SP
			↑ VMA
			↑ Fines

**Table 5: Mix Design Of SCC Using Natural And Recycled Concrete Aggregate**

Trial mix	Binder kg/m <sup>3</sup>	Cement kg/m <sup>3</sup>	Fly ash (25%) kg/m <sup>3</sup>	F.A kg/m <sup>3</sup>	C.A kg/m <sup>3</sup>		Water kg/m <sup>3</sup>	SP (%)	SP kg/m <sup>3</sup>	w/p ratio	Type of aggregate
					10 mm	16 mm					
SCC	500	375	125	900	468	312	165	0.6	3.3	0.33	Natural aggregate
SCC	550	412	138	1000	415	280	182	0.9	4.95	0.33	Recycled aggregate

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## III. EXPERIMENTAL RESULTS AND DISCUSSIONS

The hardened concrete properties of concrete such as compressive strength and split tensile strength were tested by compressive testing machine (CTM) in the laboratory. The results are presented by plotting graph and discussed Also, presented the graph for compared the all strength value of different proportion.

### 1. Fresh Properties

Fresh properties of SCC are plays major role. The fresh properties shows the concrete is able to flow under it's weight even in the presence of congested reinforcement without segregation .the workability of SCC is higher than "very high" degree of workability mention in IS 456:2000.the following test are required to check the fresh properties of SCC with different requirements.

#### A. Slump Flow Test

The slump flow are to be carried out for filling ability requirements of SCC slump flow shows the concrete is able to flow under it „own weight or not. It also indicates the resistance to segregation As per the EFNARC guidelines minimum value for slump flow is 650 mm and maximum value is 800mm.the higher he value greater is the ability to fill formwork.

#### B. V-funnel and V-funnel T5 min Test

The V-funnel flow time is the period a defined volume of SCC needs to pass a narrow opening and gives an indication of the filling ability of SCC provide that blocking and/or segregation do not take place; the flow time of the v-funnel test is to some degree related to the plastic viscosity. By using V-funnel and V-funnel T5 min Test concluded that with replacement of RCA to natural aggregate the value of test increase. The minimum and maximum value for V-test is 8 to a12 sec.

#### C. J-Ring Test

The procedure for J-Ring Test is same as slump flow test but in base plate rectangular section of 30mm\*25mmring are placed and this test checked the passing ability of concrete from reinforcement The value for J-ring is between 0 to 10 mm.

#### D. L-Box Test

This test very important for SCC fresh properties .It shows the passing ability. the test assesses the flow of concrete and also extent to which the the concrete is subjected to blocking by reinforcement. The value for L-Box is limited to 0.8 to 1.0

**Table 6: Workability Results.**

Mix	Slump flow (mm)	J-Ring(m m)	V-funnel (sec)	V-funnel T5 min (sec)	L-Box H2/H1
M1 NA100R A0	705	07	9.8	11.66	0.9
M1 NA90RA 10	727	06	8.3	10.2	1.0
M1 NA80RA 20	720	05	8.5	10.5	0.95
M1 NA70RA 30	712	04	9.0	10.8	0.85
M1 NA60RA 40	710	04	9.2	11	0.8

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The following graph shows the different value for different replacement of RCA. From this graph concludes that with increase in replacement the workability of SCC decreases.

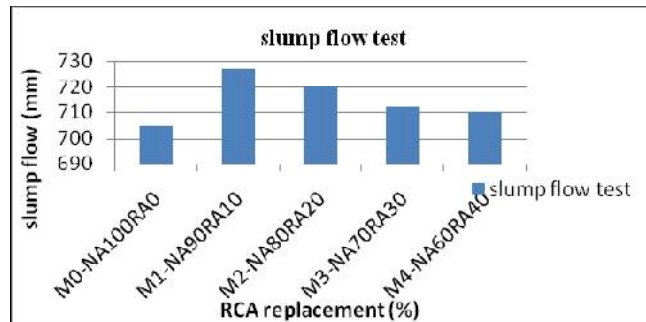


Figure 2 Slump flow

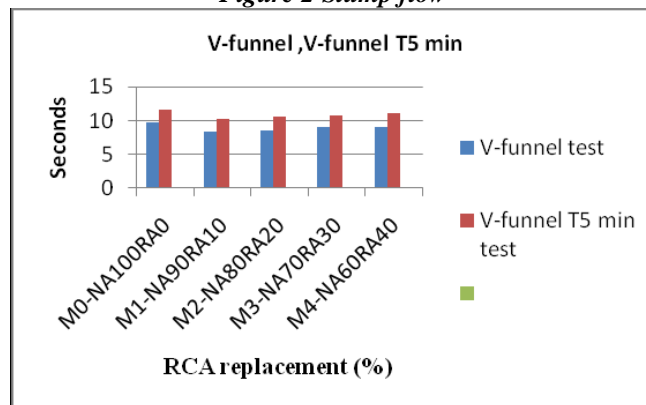


Figure 3 V-funnel

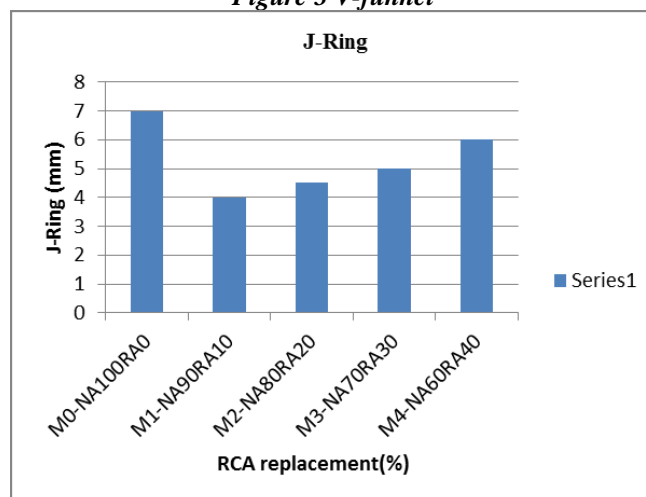


Figure 4 J-Ring test

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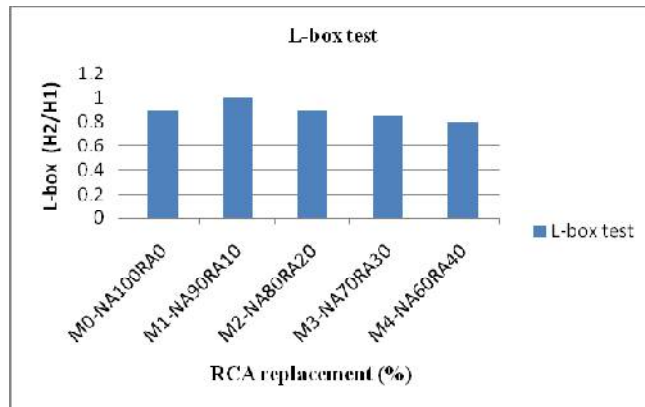


Figure 5 L-Box test

## 2. Hardened Properties

### A. Compressive strength

The size of the cube specimen is 150 mm × 150 mm × 150 mm. six concrete cubes were casted for each concrete mix proportions. The compressive strength of three cubes are measured after 7 and 28 days and take the average of these strength. Fig 1 shows the relation between compressive strength of cubes and RCA replacement ratio for 7 days and 28 days These plots show the compressive is almost equal to the 10,20,30% replacement of RCA after that 40 % replacement strength decrease so up to 30%replacement is possible. As percentage of RCA increases, the compressive strength of SCC decreases.. The compressive strength of SCC decreases with increase in RCA replacement ratio in 7 days and 28 days tests. The compressive strength increases with increase in curing time.

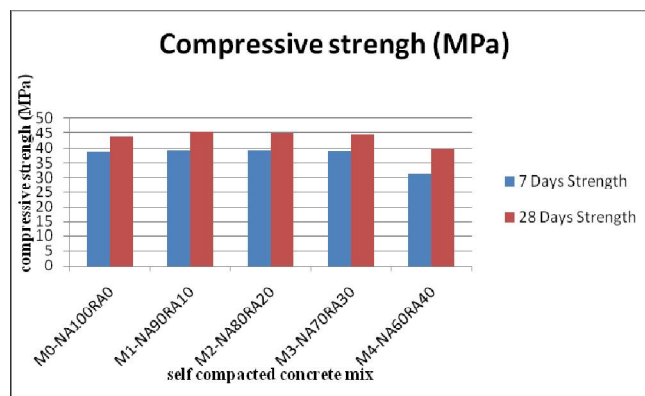


Figure 6 Compressive strength

### B. Split tensile strength

For split tensile strength the cylinder of size 150 mm diameter and 300mm length were used. six cylinder for each concrete mix were casted .three cylinder for 7 days testing and three cylinder for 28 days testing. these cylinder are demouled after 24 hours of casting .take the average of these three split tensile strength. Fig 7 shows the relation between split tensile strength of cylinder and RCA replacement ratio for 7 days and 28 days These plots show the split tensile strength is almost equal to the 10,20,30% replacement of RCA after that 40 % replacement strength decrease. for calculating the split tensile strength have equation and it is  $2P/3.14DL$ .



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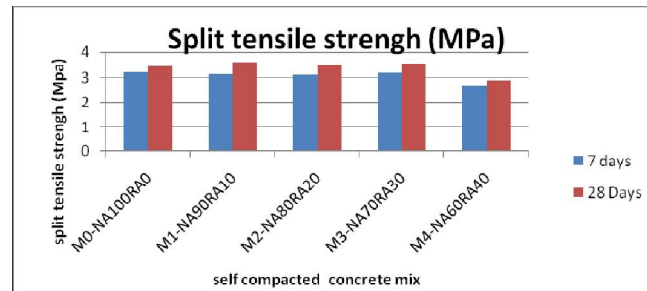


Figure 7 Split tensile strength

## IV. CONCLUSION

- ❖ Mix design of self-compacted concrete is required to follow EFNARC guidelines.
- ❖ In this study, it has been found that the workability increase with increase in dosage of super plasticizer.
- ❖ Higher dosage of super plasticizer can lead the high degree of segregation in SCC and after 24 hours when try to demoulded cubes AND cylinder then it can collapsed.
- ❖ RCA show higher water absorption compared with conventional NCA due to old mortar attached with original concrete and has relatively lower specific gravity.
- ❖ Overall cost of SCC may be slightly higher compared to same grade of conventional concrete mainly due to cost of chemical admixtures. However, partly the additional cost is compensated by reducing the cost of compaction and achieving speed during construction.
- ❖ The workability decreases with increases RCA replacement to natural aggregate because of weak properties of RCA than natural aggregate.
- ❖ Result of L-Box can be achieve by reduce coarse aggregate content ,reduce the size of aggregate and increase the sand content.
- ❖ Compressive and Split Tensile Strength decreases with increases replacement of natural aggregate to recycled aggregate.
- ❖ In 28 days the compressive strength 5.25 MPa and split tensile strength 0.67 MPa is reduced for a 40%replacement compared to 30%.
- ❖ The test result indicates that the compressive and split tensile strength is same to the 10, 20, 30% replacement of RCA. After that the both strength value is reduced by 40%replacement so up to 30% replacement is possible.

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