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Behavior of Self-Compacting Concrete Using Using Pozzolanic Materials

Mr. H.S.Narashimhan[1], Dr. Karisiddappa[2] and Dr. Ramegowda M[3]
[1] Associate Professor, Department of Civil Engineering, Malnad College of Engineering, Hassan, Karnataka state, India.
[2] Dr. Karisiddappa, Vice Chancellor, Visvesvaraya Technological University Belagavi, India.
[3]Dr. M. Ramegowda, Professor and Head, Department of Civil Engineering, AIT, Chikmagalur, India
Corresponding Author: Mr. H.S.Narashimhan

Abstract: *Self-Compacting Concrete (SCC) is a type of concrete that has the capacity to consolidate under its own weight. Self compacting concrete has ability involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when the concrete flows through the congested reinforcement. One of the major challenges faced by civil engineering industry is to execute projects in harmony with the nature. In the present study is focused to investigate the rheological properties and strength properties of bagasse ash and rice husk ash self compacting concrete produced with 0%, 10%, 20% and 30% of the cement (by mass) replaced by bagasse ash and rice husk ash and sand replaced by 20%, 30%, 40%, 50% and 70% by quarry dust. For Fresh property was done for all the replacement and hardened properties were done at 7, 28, 91 and 180 day for compressive strength, 7, 28 and 120 day for split tensile strength and flexural strength. Attempts have been made to study the properties of such SCC and to investigate the suitability of Quarry Dust to be used as partial replacement materials for sand in SCC.*

Keywords: *Bagasse ash, compressive strength, flexural strength quarry dust, Rice husk ash, split tensile strength and Self Compacting Concrete.*

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I. Introduction

The development of Self-compacting concrete (SCC) removes the need for compaction when placing of fresh concrete. It is highly flowable, non segregation concrete, it can spread all the space of the formwork. This saves time, reduces the cost, and improves quality of concrete and working environment [1]. Professor Okamura in Japan proposed a concept for a design of concrete independent of the need for compaction in 1986. An invention of self Compacting Concrete (SCC) can be considered as a major evolution in the construction industry. SCC has very little resistance to flow so that it can be placed and compacted under its own weight without any vibration. The general purpose mix design method was first developed by Okamura and Ozawa [2]. The mix design of SCC must satisfy the criteria on filling ability, passing ability and segregation resistance, these three test methods criteria and limiting values are given [3]. Inert fillers such as limestone are used in SCC mix to increase the powder content [4], these fillers are the moisture variations in concrete, which control shrinkage and creep strain [5], To design SCC mix by using Nan Su method. The Nan-su method is valid for grades more than M50 but with some modifications. It was observed that the flow property is better with metakaoline compared to fly ash or silica fume in all the grades tested. The addition of VMA increases the viscosity of concrete, thereby the flow and filling abilities are improved [7]. As SCC requires high cement content which leads to increase in cost and temperature rise during heat of hydration, additives or pozzalanic material such as fly ash, rice husk ash metakoalin, limestone powder or slag can generally be used as partial replacement of cement to reduce the cost and heat of hydration [8]. The limestone power is used in the production of SCC at different curing conditions and their properties of were compared with conventional concrete [12].

The superplastizer is necessary for producing a highly fluid concrete mix, while powder materials or viscosity agent are required to maintain sufficient stability/cohesion of the mix, hence reducing bleeding, segregation and settlement. Increase in the cement content leads to a significant rise in material cost and often other negative effect on concrete properties like shrinkage and chemical attack etc. Sugarcane is one of the major crops grown in most of the countries and its total production is over 1800 million tons all over the world. For each 10 tonnes of sugarcane crushed, a sugar factory produces nearly 3 tonnes of wet bagasse. The utilization of low percentage bagasse ash dust and rice husk ash in the concrete, cost saving. Obliviously the material cost depending upon the source [9] The quarry dust is the by-product which is formed in the processing of the granite stones which broken downs into the coarse aggregates of different sizes. Quarry dust has been proposed as an alternative to river sand that gives additional benefit to concrete. In the production of SCC. However, due to its shape and particle size distribution mixes with quarry dust required a higher dosage of superplasticiser to achieve similar flow properties. [10]. The M sand is an alternative for sand in the production of SCC, it was observed that relatively higher paste volume is essential to achieve the required flow for SCC using M-sand ,as compared to river sand. Low and medium strength (25–60 MPa) SCCs were achieved by using M-sand [11]. The main objective of this paper study the fresh concrete properties such as filling ability and passing ability and mechanical properties such as compressive strength, split tensile strength, flexural strength of SCC made with up to 30 percent replacement. The results are compared to those obtained with a control mix.

II. Materials Used

2.1 Cement

Cement is the fine material which is used as a binding material. Ordinary Portland cement 43 grade was used. It is confirming to the requirement Indian standard specification IS :8112-1989 [13]. The physical properties are given in Table 1. The tests on cement have been carried out as IS : 4031- 1999.

Table 1 Properties of Ordinary Portland cement

Sl.No.	Physical test		Results obtained	Requirement IS: 8112-1989
1	Fineness (retained on 90µm sieve) (%)		5.50	10 maximum
2	Specific gravity		3.05	-
3	Vicat time of setting (minutes)	Initial setting time	80	30 minimum
		Final setting time	325	600 maximum
4	Compressive Strength (MPa)	3 day	24.00	23.00 minimum
		7 day	35.00	33.00minimum
		28 day	45.20	43.00 minimum

2.2 Fine Aggregate

Fine aggregate used in the present study is from the river bed of Hemavathi river Holenarasipur. The sieve analysis of fine aggregate has been carried out as per IS 383-1970[15] and from that it is confirmed to grading zone-II and other properties of fine aggregate are shown in Table 2.

Table 2 Physical Properties of Fine Aggregate

Sl. No.	Physical Properties		Results Obtained	Requirement as per S :383-1970
1	Fineness modulus		2.97	2.20 - 3.20
2.	Specific gravity		2.55	
3	Surface moisture (%)		1.45	< 2
4	Water absorption (%)		1.53	< 2
5	Bulk density (Kg/m^3)	Loose state	1455.00	
		Rodded state	1545.00	
IS sieve Designation (mm)	Weight retained (grams)	Cumulative percent retained	Percent Passing	Requirement as per IS :383-1970, Zone II
4.75	0	0	100	90-100
2.36	165	16.5	83.5	75-100
1.18	190	35.5	64.5	55-90
0.60	230	58.5	41.5	35-59
0.30	300	88.5	11.5	8-30
0.15	100	98.5	1.5	0-10
Pan	15	100	0	-

2.3 Coarse Aggregate

The common coarse aggregates are crushed stone and gravel. The 16 mm downsize coarse aggregate was and tested as per IS 2386 (I, II, III) specifications and the properties are given in Table 3. It is confirming to the requirement Indian standard specification IS :383-1970 [15].

Table 3 Properties of Coarse Aggregate

Sl. No..	Physical Properties		Results Obtained	Requirement As Per IS:383-1970
1	Shape		Angular	
2.	Specific gravity		2.62	
3	Surface moisture(%)		Nil	< 0.60%
4	Water absorption (%)		0.15	< 0.60%
5	Bulk density (Kg/m^3)	Loose state	1465.00	
		Rodded state	1595.00	

IS sieve (mm)	Weight retained (grams)	Cumulative percent Retained	Percent passing	Requirement as per IS :383-1970 in respect of 16 mm nominal size aggregate (% passing)	
				Graded	Single size
20	0.000	0.0	100.0	100	100
16	590	11.8	88.2	90-100	85-100
12.5	1780	47.4	52.6		
10	1415	75.7	24.3	-	-
6.3	890	93.5	6.5	30--70	0-30
4.75	325	100.0	0.0	0-10	0-5

2.4 Quarry Dust

Quarry dust comprises of the smaller aggregate particles, so it was sieved and quarry dust passing from 4.75mm IS sieve and retaining on 150 micron IS sieve is used for the replacement of fine aggregate. The sieve analysis of fine aggregate has been carried out as per IS 383-1970 [15] and from that it is confirmed to grading zone-II and other properties of fine aggregate are shown in Table 4.

Table 4 Physical Properties of Bagasse Ash

Sl. No.	Physical Properties		Results Obtained	Requirement As Per IS :383-1970
1	Fineness modulus		2.88	2.20 - 3.20
2.	Specific gravity		2.45	2.60-2.70
3	Surface moisture (%)		2.35	
4	Water absorption (%)		2.80	
5	Bulk density (Kg/m^3)	Loose state	1520.00	
		Rodded state	1615.00	

IS sieve (mm)	Weight retained (gms)	Cumulative % Retained	% Passing	Requirement as per IS :383-1970, Zone II
4.75	0	0	100	90-100
2.36	142	14.2	85.8	75-100
1.18	205	34.7	65.3	55-90
0.60	282	62.9	37.1	35-59
0.30	214	84.3	15.7	8-30
0.15	75	91.8	8.2	0-10
Pan	82	100	0	-

2.5 Water

Generally tap water is used in this experiment. The water which is used should be free from salt. It is very important ingredient in the concrete mass, as it actively participates in a chemical reaction with cement.

2.6 Rice Husk Ash

The rice husk ash had greyish white colour. RHA was passed through IS 90 micron sieve and this was used. The specific gravity at 27oC is 2.18 and bulk density is 895 kg/m3 determined as per IS 1727-1967 [14]

2.7 Bagasse Ash

The bagasse ash is collected from Hemavathi sugar factory near Channarayapatna (Karnataka state) was used in this study. The ash obtained in the factory was coarser and it was put to the ball mill to convert them into fine particles of size most likely to the cement particles. Bagasse ash has grayish white color. Bagasse ash was passed through IS 90 micron sieve and this was used for the research. The specific gravity at 27oC is 2.32 and bulk density is 1075 kg/m3 determined as per IS 1727-1967 [14]

2.8 Chemical Admixture

Admixtures mainly affect the flow behavior of the Self-compacting concrete. The admixture used here is sika viscocrete 5231. The properties of this admixture is Specific gravity at 250C is 1.08, pH is 7.25 and bluish brown colour.

III. Mix Proportions, Preparation And Casting Of Test Specimens

Several trial mixes are prepared by changing the volume ratio of fine aggregate, coarse aggregate, water/powder ratio and super plasticizer. On the basis of the test results many trail mixes are conducted in the laboratory and final mix proportion which satisfies the fresh concrete properties as per EFNARC 2002 [3] guidelines is selected for control concrete mix. The final mix proportion is the reference mix of SCC mixes with different replacement level of bagasse ash, RHA and QD For all the mixes coarse aggregate content is kept constant are given in Table 5. These mixes are tested as per EFNARC [3] and satisfied their requirements. The test specimens were cast in one layer in steel moulds without any vibration or tamping, all the specimens are then cured in water until the specified date of testing [16]

Table 5 Mix proportion for SCC mixes

Mix Notation	Cement (kg/m^3)	BA (kg/m^3)	RHA (kg/m^3)	FA (kg/m^3)	QD (kg/m^3)	CA (kg/m^3)	W/c ratio	SP (%)
BR1	450	0	0.00	891.00	0.00	742.50	0.46	0.50
BR2	405	22.50	22.5	712.00	179.00	742.50	0.46	0.50
BR3	405	22.50	22.50	623.70	267.30	742.50	0.48	0.50
BR4	405	22.50	22.50	534.60	356.40	742.50	0.48	0.50
BR5	405	22.50	22.50	445.50	445.50	742.50	0.50	0.60
BR6	405	22.5	22.5	267.30	623.70	742.50	0.55	0.60
BR7	360	45.00	45.00	712.00	179.00	742.50	0.50	0.50
BR8	360	45.00	45.00	623.70	267.30	742.50	0.52	0.55
BR9	360	45.00	45.00	534.60	356.40	742.50	0.52	0.50
BR10	360	45.00	45.00	445.50	445.50	742.50	0.55	0.60
BR11	360	45.00	45.00	267.30	623.70	742.50	0.55	0.60
BR12	315	67.50	67.50	712.00	179.00	742.50	0.52	0.50
BR13	315	67.50	67.50	623.70	267.30	742.50	0.53	0.65
BR14	315	67.50	67.50	534.60	356.40	742.50	0.55	0.50
BR15	315	67.50	67.50	445.50	445.50	742.50	0.55	0.70
BR16	315	67.50	67.50	267.30	623.70	742.50	0.55	0.65

IV. Testing Of Specimens

The fresh concrete properties such as filling ability and passing ability (Slump flow test, SlumpflowT50 cm, J-ring test, V-funnel test, V-funnel 5 minutes and L box were carried out according to EFNARC [2]. Hardened concrete properties such as compressive strength, split tensile strength and flexural strength [16].

V. Results And Discussion

5.1. Fresh Concrete Properties

Table 6 Rheological Properties of SCC Mixes

Mix Notation	Slump Flow (mm)	$T_{50\,cm}$ Slump Flow (sec)	J Ring (mm)	V- funnel (sec)	V- funnel T5 min. (sec)	L-Box
BR1	640	7	9	8	11	0.83
BR2	665	6	8	6	8	0.84
BR3	649	5	8.5	11	14	0.87
BR4	630	7	5	10	13	0.81
BR5	605	7	5	11	13	0.92
BR6	690	5	8	10	14	0.93
BR7	665	6	8	6	8	0.85
BR8	590	7	14	14	17	0.85
BR9	630	5	6	10	14	0.85
BR10	645	6	9	10	13	0.82
BR11	650	6	10	10	14	0.89
BR12	660	6	10	7	9	0.83
BR13	613	7	12	12	15	0.86
BR14	650	7	5	12	14	0.91
BR15	654	5	8	11	14	0.82
BR16	652	6	9	10	14	0.8

From the above table, it can be seen that the control mix got 640 mm slump flow. As the replacement of cement increase, the slump flow also increases. The slump flow value obtained maximum is 690 mm for BA6, i.e. 10% replacement of cement and 70% replacement of fine aggregate. The slump flow values of various mixtures were between 590 mm to 690 mm, a slump flow between 650 mm to 800 mm [3], which are an indication of a good deformability. Based on the slump flow and visual observation, SCC property for all mixtures was found to be satisfactory except for the mix BR8.

Here the control mix had a 7 seconds of T50 cm slump flow time and BR3, BR6, BR9 and BR15 are having 5 seconds of T50 cm slump flow time. They have shown better result compared to all other mixes.

From the above table in L box it can be seen that the control cube is having depth ratio 0.83 and all other replacements are satisfied according to EFNARC

From the above table in V funnel test, it can be seen that the control mix is shown 8 seconds. BR8 having 14 sec. does not satisfies for acceptable limit and all other mix as shows better results.

From the above table J ring test, it can be seen that the control mix got 9 mm depth. . BR8 and BR13 does not satisfied for acceptable limit and all other mixes shows better results. The acceptable difference as per available literature is 0-10 mm.

5.2. Mechanical properties
5.2.1. Compressive strength

Table 7 Compressive Strength of SCC Mixes

Mix Notation	Experimental Compressive Strength (MPa)			
	7 Day	28 Day	91 Day	180 Day
BR1	28.17	42.17	47.78	50.09
BR2	27.11	36.95	44.04	47.13
BR3	27.15	32.83	39.07	42.32
BR4	26.58	37.17	43.02	45.95
BR5	27.86	40.92	45.86	48.47
BR6	27.15	38.98	41.68	44.30
BR7	22.02	35.20	38.09	41.23
BR8	19.42	26.52	33.89	38.11
BR9	21.84	25.17	33.20	37.76
BR10	19.40	25.93	32.87	35.68
BR11	18.80	24.93	30.29	35.42
BR12	17.26	25.60	28.93	32.93
BR13	16.38	23.20	26.56	31.86
BR14	16.08	21.93	24.67	27.82
BR15	14.33	18.95	22.00	24.57
BR16	12.35	17.26	22.41	24.30

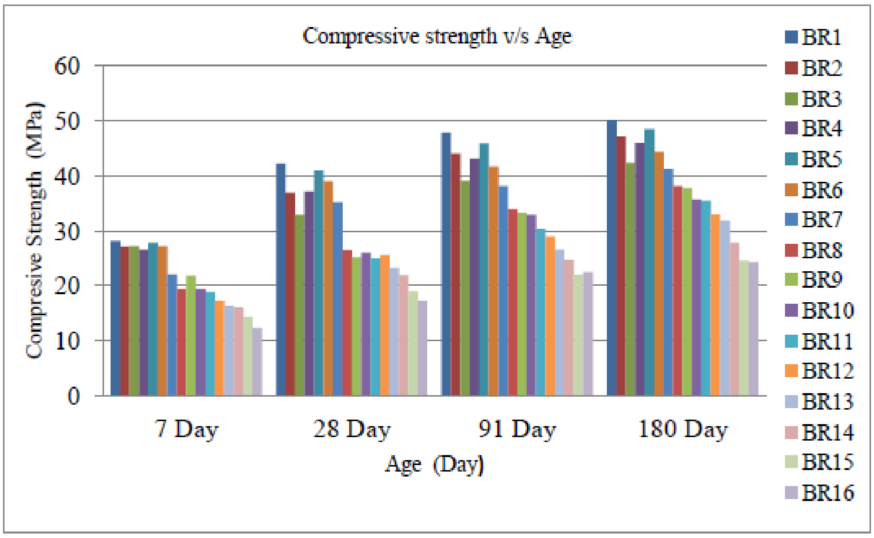

Fig. 1 Variation of Compressive Strength of Cubes with Age

The results of compressive strength of cubes for 7, 28, 91 and 180 days curing are given in Table 7. Also results are compared graphically in Fig. 1. It can be seen from Fig. 1 the compressive strength increased with a decrease in the percentage of the bagasse ash and RHA at all levels of replacement at 7, 28, 91 and 180 days and an increase trend strength is observed as the age of concrete increases. The reductions of compressive strength are 3.76 % to 56.15 % for 7 days, 2.96% to 59.07 % for 28 days, 4.01% to 53.09 % for 91 days, and 3.23 % to 51.48 % for 180 day compared with control mix. In the early age bagasse ash and RHA reacts slowly with calcium hydroxide liberated during hydration of cement and does not contribute significantly to the densification of concrete matrix. The 70% OPC, 15% bagasse ash and 15% RHA had the lowest early age compressive strength due to the slower reactivity of bagasse ash and RHA. It can be seen from the Fig. 1 up to the age of 28 days, there was progressive improvement. The mix BR5 achieved 40.92 MPa . The increase in strength from 28 to 180 days was between 13.64 to 50.01 percent. The compressive strength was strongly affected by water cement ratio and filler types. Hence 10 % replacement of cement by bagasse ash and RHA and 50 % replacement of sand by quarry dust can be taken as optimum replacement in suceesive ages of tests taken into consideartion.

5.2.2 Split Tensile Strength

The split tensile strength of concrete cylinder were tested in the laboratory conditions at the age from 7 days to 120 days and the results were given in Table 8.

Table 8 Split Tensile Strength and Flexural Strength of SCC Mixes

Mix Notation	Split Tensile Strength (MPa)			Flexural Strength (MPa)		
	7 day	28 day	120 day	7 day	28 day	120 day
BR1	2.22	3.28	4.34	2.54	3.65	4.23
BR2	2.17	3.02	3.52	2.45	3.52	3.89
BR3	2	2.55	3.15	2.18	2.97	3.73
BR4	1.85	2.85	3.18	2.10	2.76	3.67
BR5	2.08	2.88	3.62	2.08	2.87	3.88
BR6	1.52	2.59	3.25	1.87	2.56	3.68
BR7	1.71	2.24	2.94	1.65	2.43	3.41
BR8	1.66	2.25	2.84	1.70	2.36	3.2
BR9	1.51	2.2	2.88	1.66	2.22	3.04
BR10	1.51	2.2	2.88	1.53	2.15	2.78
BR11	1.33	1.91	2.74	1.60	2.21	2.65
BR12	1.24	1.77	2.48	1.50	2.18	2.61
BR13	1.19	1.67	2.28	1.50	2.01	2.55
BR14	1.19	1.67	2.28	1.43	1.98	2.43
BR15	1.19	1.65	2.18	1.46	1.93	2.87
BR16	1.05	1.57	2.18	1.29	1.94	2.65

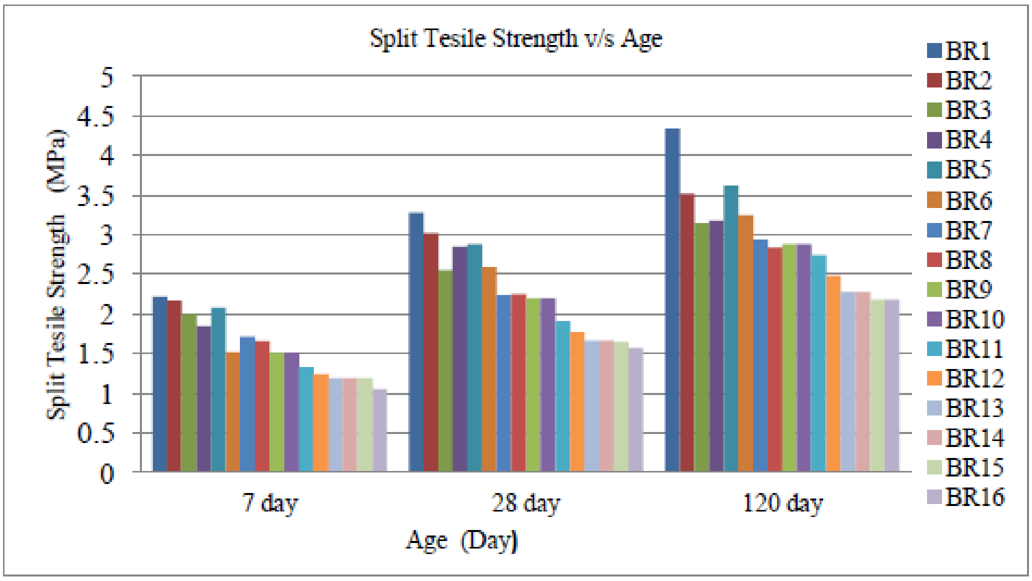

Fig. 2 Variation of Split Tensile Strength of Cylinder with Age

The split tensile strength increased with a decrease in percentage of bagasse ash and RHA. The results of split tensile strength of cylinder for 7, 28 and 120 day curing are given Table 8. Also results are compared graphically in Fig. 2 It can be seen from the Fig. 2 that the split tensile strength at 28 days curing for control mix BR1 achieved 3.28 MPa. Mixes BR2 to BR16 showed increase of 21.56 to 41.31 percent from 7 days to 28 days. Mixes BR1 to BR16 showed increase of 11.57 to 40.11 percent from 28 days to 120 days. The significant increase in strength of concrete is due to pozzolanic reaction of bagasse ash and RHA.

5.2.3 Flexural Strength

The flexural strength of concrete beam were tested in the laboratory conditions at the age from 7 days to 180 days and results were given in Table 8.

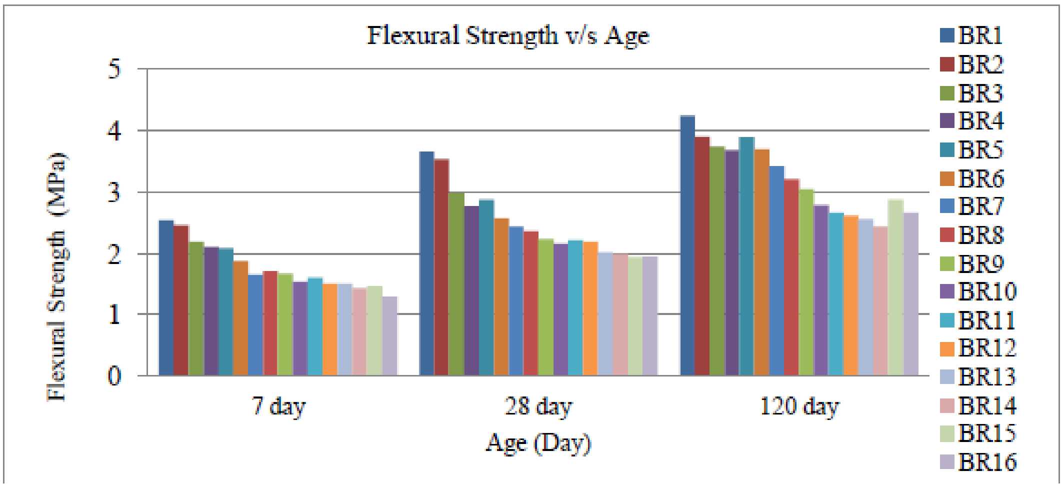

Fig. 3 Variation Of Flexural Strength of beams with Ages

The flexural strength of concrete mix also increased with decrease in bagasse ash and RHA percent. The results of flexural strength at 7, 28 and 120 and curing are given in Table 8. It can be seen from the Fig. 3 that the flexural strength at 28 days curing for control mix BR1 achieved 3.65 MPa. The mixes BR2 to BR16 showed increase of 24.35 to 33.50 percent from 7 to 28 days, from 28 days to 120 days strength increased by 10.51 to 48.70 percent. The optimum flexural strength is achieved by BR 5 i.e. 10 percent replacement of baggase ash and RHA and QD 50 percent.

VI. Conclusion

- The use of by item mineral admixtures is the best option for these days since it not just influences the solid to achieve the best possible execution yet additionally lessen the solid cost and ecological issues.
- Percentage of replacement of cement by bagasse ash and RHA increases the slump flow, T50cm slump flow, J-ring, V funnel and L box decreases. The reduction in viscosity of SCC, the time required for slump flow value decreases
- The fresh concrete property is obtained better for BR6 i.e. 10% partial replacement of RHA and BA to cement and 70% of quarry dust to fine aggregate when compared to all other replacement as well as 0% replacement.
- The compressive strength increased with a decrease in the percentage of the bagasse ash and RHA, but 28 days compressive strength achieved target strength 40.92 MPa was that made with 10% partial replacement of RHA and BA to cement and 50% of quarry dust to fine aggregate when compared to other replacement for 28 day strength. The significant increase in strength bagasse ash and RHA concrete is due to pozzolanic reaction.
- The splitting tensile strength decreases as the percentage of replacement increases for all the mixes. The split tensile strength of SCC is obtained maximum for BR i.e. 10% partial replacement of RHA and BA to cement and 50% to fine aggregate
- Like compressive strength and splitting tensile strength results, the flexural strength of concrete mixtures also increased with decreased in bagasse ash and RHA percent.

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