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The Structural Performance of RCC Beams Made With M30 Grade SCC Mix While Fine Aggregate Is Partially Replaced By Crystal Stones

P. Sivakumar, N. Balasundaram, V.Karthik &K.Vivek

Abstract - The economy of a developing country depends to a great extent on the construction industry. Developing countries like India are investing heavily in infrastructure development. The excessive exploitation of natural resources for construction threatens the sustainability of aggregates and poses a number of serious problems. At the same time, the disposal of fly ash and stone residues in landfills cause several environmental crises and pollute the environment. This article deals with a study on the structural behavior of the partial replacement of fine natural aggregates by 0 -40% crystal stones in order to obtain the flow properties of fly-ash-based self-compacting concrete (SCC) by using super plasticizers. Many tests have been done to test the feasibility of using crystal stones in M30 grade SCC. On the basis of the results obtained, the optimum percentage of fine aggregates with crystal stone was calculated at 30% and it was concluded that the increasing percentage of crystal stone replacement by fine aggregates did not affect its workability. The structural performance of simply supported RCC beams of size 150 × 200 × 1500 mm made from SCC with crystalline stone was tested.

Keywords: Fly-ash based SCC, Crystal stone, Mechanical and Structural properties.

I. INTRODUCTION

Concrete that flows and settles under its own weight, even in the occurrence of heavy reinforcement without segregation, bleeding or external vibration, is termed as SCC[4].In this way, environmental difficulties could be avoided like noise and vibrations. Concrete mix is selected to satisfy visual stability index criteria for the concrete. No standard mix design is available for SCC mix design; SCC was produced in the construction field by keeping their own proportion of mix which satisfies VSI criteria.

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* Correspondence Author
P. SIvakumar*, Research Scholar, Department of Civil Engineering, Karpagam Academy of Higher Education, Coimbatore, Tamilnadu, India.
Dr. N. Balasundaram, Professor, Department of Civil Engineering, Karpagam Academy of Higher Education, Coimbatore, Tamilnadu, India.
Dr. V. Karthik, Associate Professor, Department of Civil Engineering, SRk Institute ofTechnology, Vijayawada,India.
Dr.Vivek, Assistant Professor, Department of Civil Engineering, Paavai Engineering College, Namakkal, Tamilnadu, India.

Fly ash generated from thermal power plants meets the increasing demand on source materials of concrete, and serves as a better substitute for cement. In this study, fly ash was utilized as the source binding material in SCC, which could help reduce environmental problems like CO_2 emission on OPC production and disposal of waste. Due to scarcity and restrictions on river sand, its cost is increasing rapidly. Enormous depletion of the resource also causes soil erosion. To avoid such situations and to meet the demand, we have to consider a useful alternative or replacement material for natural sand. Some of the conventional options are crushed rock material, sea sand, fly-ash, marble dust powder, etc. In this study, crystal stone of varying percentage was used to replace the natural sand used in the fly-ash based SCC.

II. MATERIALS USED

The list of materials used in this study is given below:

a. Cement

For this study, an OPC grade of 53 was used, thus confirming IS: 12269 – 2004, and the basic properties of cement are illustrated in Table 1.

Table 1: Properties of Cement

Parameter	S.G*	Consistency	Fineness	Setting Time (min)	
				Initial	Final
Results	3.18	32%	6.10	38	568

[S.G* - Specific Gravity]

b. Fly ash

Pulverized fine-grained fly ash, dark grey in color and collected from the nearby power plant, was used in the study as per IS 3812:2003, which possesses specific gravity of 2.48.

c. Fine Aggregate (FA)

Fine aggregate used in this experimental study was conforming to zone II of IS 383-1970 (Part-4).

Table 2: Properties of Fine Aggregate

Parameter	S.G*	W.A*	F.M*
Results	2.52	6.6%	2.89

[W.A* - Water Absorption; F.M* - Fineness Modulus]

d. Crystal Stones

Locally available crystal stones taken from the nearby quarries were used in this study. The properties are mentioned in table 3.

Table 3: Properties of Crystal Stones

Parameter	S.G*	W.A*	F.M*
Results	2.41	5.6%	2.84

e. Coarse Aggregate (CA)

A locally available rounded aggregate was used, had a specific gravity of 2.74 and water absorption of 2.5%.

f. Water

Throughout the investigation, drinking water of pH value 6.7, complying with IS 456: 2000, which contained no harmful external agents, was used for mixing and curing.

g. Super plasticizers

For the preparation of SCC, Master Glenium SKY 8233 was used as a super plasticizer.

III. MIX DESIGN

The mix design was in accordance with the guidelines of IS 10262: 2009 for the design of M30 concrete. The details of the mix ratio are presented in Table 4.

Table 4: Mix Proportion for SCC

Ingredients	Conventional SCC		Fly ash based SCC	
	Quantity (kg/m^3)	Mix Proportion	Quantity (kg/m^3)	Mix Proportion
Cement	521.28	1	-	-
Fly ash	-	-	525.11	1
FA	765.23	1.47	764.18	1.46
CA	788.24	198.45	790.19	1.50
Water	1.51	0.38	199.24	0.38

IV. MECHANICAL STRENGTH PROPERTIES

Usage of fly-ash in SCC reduces various environmental problems, and the 30% replacement of crystal stones with fine aggregate shows improved results. Strength Properties increased by 24.06%, 25.53% and 41% respectively at the optimum percentage of replacement than conventional SCC.

Table 5: Summary of Mechanical Strength Properties

Strength Properties at varying curing period (MPa)		Mix ID	CC-SCC	FA-SCC-30%S	% Increase
	Compressive	3	18.56	19.58	5.50
		14	29.22	29.93	2.43
		28	35.76	38.16	6.71
		56	40.15	49.81	24.06
	Split Tensile	3	2.86	2.98	4.2
		14	3.21	4.42	37.69
		28	3.59	4.81	33.98
		56	4.27	5.36	25.53
	x u	3	3.67	5.65	53.95
		14	4.28	6.19	44.63
		28	4.68	6.51	39.1
		56	5.17	7.29	41.01

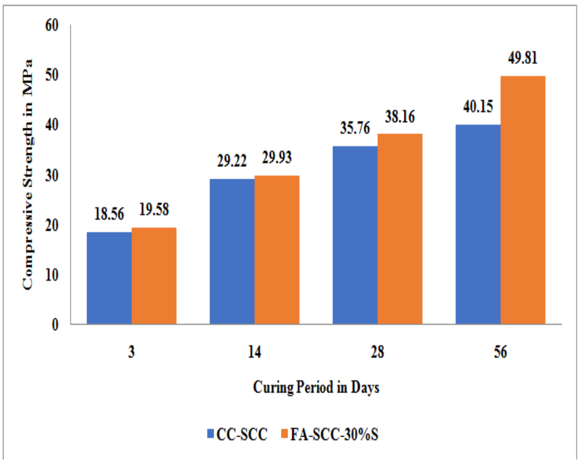

Fig. 1: Compressive Strength Comparisons

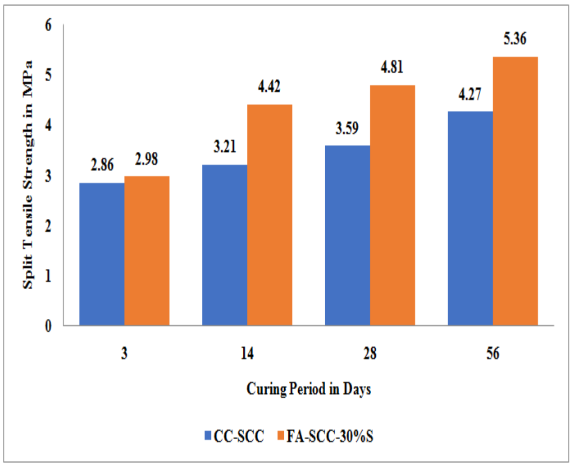

Fig. 2: Split Tensile Strength Comparisons

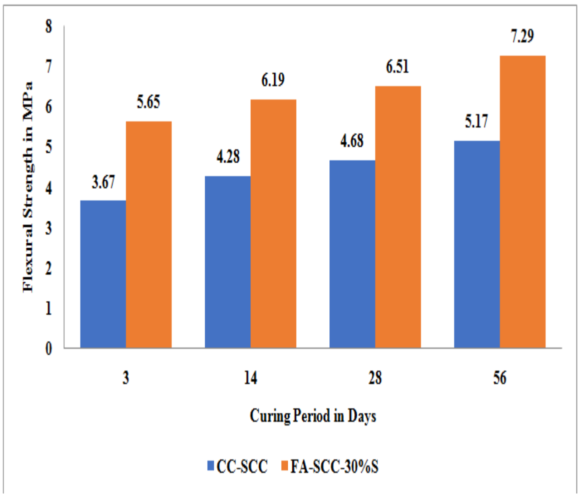

Fig. 3: Flexural Strength Comparisons

II. STRUCTURAL PERFORMANCE OF RCC BEAMS

The beam specimens were casted with Fe415 grade steel. The details of reinforcements are shown in Figure 4.

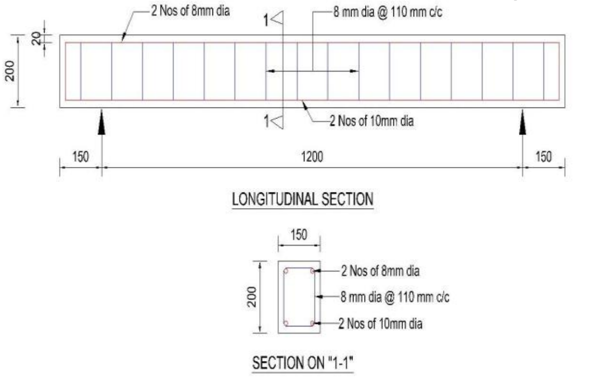

Fig. 4: Reinforcement Detailing of RCC beam

Table 6: Load vs Deflection Behavior of fly ash based SCC

Load (kN)	Mid Span Deflection (mm)				
	CC-SCC	FA-SCC-10%S	FA-SCC-20%S	FA-SCC-30%S	FA-SCC-40%S
0	0	0	0	0	0
1	0.11	0.1	0.1	0.08	0.2
8	0.26	0.24	0.24	0.23	0.27
12	0.42	0.4	0.38	0.36	0.43
15	0.65	0.63	0.61	0.59	0.69
21	0.77	0.75	0.74	0.71	0.82
24	0.94	0.91	0.87	0.85	**1.02 F**
27	**1.09 F**	1.03	1.01	0.98	1.16
28	1.3	**1.26 F**	1.19	1.15	1.37
30	1.62	1.57	**1.51 F**	1.37	1.63
34	1.69	1.64	1.63	**1.57 F**	1.85
37	1.95	1.89	1.81	1.76	2.11
41	2.37	2.3	2.22	2.14	2.59
46	3.25	3.15	3.04	2.92	3.54
49	4.14	4.02	3.88	3.73	4.46
54	5.44	5.29	4.93	4.74	5.71
57	6.85	6.65	6.34	6.12	7.34
60	8.38	8.16	7.84	7.62	9.16
64	9.31	9.01	8.65	8.4	10.07
67	10.15	9.95	9.55	9.27	12.19
71	11.23	10.89	10.48	10.16	13.68
73	12.51	12.16	11.77	11.4	15.13
75	**13.01 U**	12.94	12.45	11.98	**15.87 U**
79	-	**13.57 U**	13.04	12.61	-
83	-	-	**14.89 U**	14.19	-
86	-	-	-	**15.21 U**	-

***F – First Crack; U – Ultimate Crack**

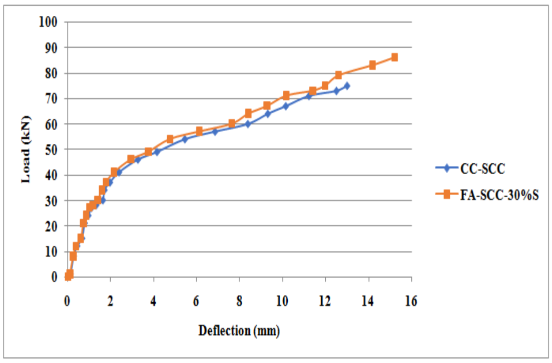

Fig. 5: Load vs Deflection curve for CC-SCC and FA-SCC-30%S

Table 7: Flexural behavior of Reinforced Concrete Beam

Flexural behavior		Specimen				
		CC-SCC	FA-SCC-10%S	FA-SCC-20%S	FA-SCC-30%S	FA-SCC-40%S
First Cracking Load(kN)		27	28	30	34	24
Deflection at first Crack (mm)	L/3	0.91	1.13	1.34	1.42	0.85
	L/2	1.09	1.26	1.51	1.57	1.02
	L/3	0.94	1.15	1.34	1.47	0.89
Ultimate Load(kN)		75	79	83	86	75
Deflection at Ultimate Load (mm)	L/3	12.56	12.76	13.48	14.17	14.29
	L/2	13.01	13.57	14.89	15.21	15.87
	L/3	12.52	12.77	13.52	14.26	14.32
Mode of Failure observed		Flexural				

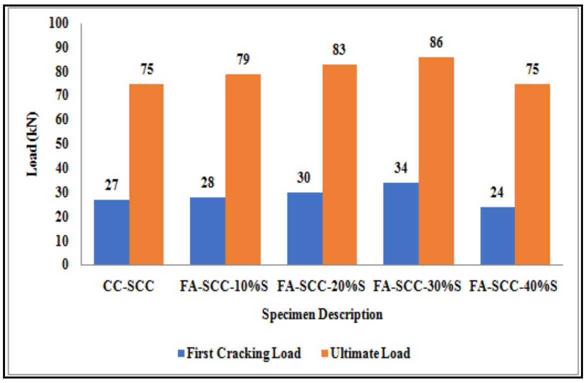

Fig. 6: First Cracking load and Ultimate load of RCC

Table 8: Comparison of load carrying capacity when Initial crack occurs

Specimen	First Crack Load (kN)	Difference in Strength with CC (kN)	% Difference in Strength with CC
CC-SCC	27	-	-
FA-SCC-10%S	28	1	3.70 (↑)

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FA-SCC-20%S	30	3	11.11 (↑)
FA-SCC-30%S	34	7	25.93 (↑)
FA-SCC-40%S	24	-3	11.11(↓)

Table 9: Stiffness of the Beam

Specimen	Ultimate Load (kN)	Ultimate Deflection (mm)	Stiffness (kN/mm)
CC-SCC	75	13.01	5.76
FA-SCC-10%S	79	13.57	5.82
FA-SCC-20%S	83	14.89	5.57
FA-SCC-30%S	86	15.21	5.65
FA-SCC-40%S	75	15.87	4.73

Table 10: First crack and ultimate loads of fly ash based SCC

Specimen	Load at Initial Crack P_{cr} (kN)	Ultimate load P_u (kN)	P_{cr}/P_u (%)
CC-SCC	27	75	36
FA-SCC-10%S	28	79	35.44
FA-SCC-20%S	30	83	36.14
FA-SCC-30%S	34	86	39.53
FA-SCC-40%S	24	75	32

III. CONCLUSIONS

Following are the conclusions drawn from the detailed investigation done on the RCC beams made with fly ash based SCC.

- The results show that by partially replacing and with crushed crystal stone a durable concrete could be produced.
- SCC made with fly ash and crystal stone fulfilled the VSI criteria as per the guidelines mentioned in EFNARC.
- FA-SCC-30%S shows better results in determining the strength properties such as compressive, tensile and flexural strength, of 24.06%, 25.53% and 41% respectively with the optimal replacement percentage compared to CC-SCC. .
- The failure load was not affected by the initial cracking.
- Structural performance of RCC beams increased upto 30% with replacement of fine aggregate with crystal stone, and beyond 30%, the structural performance decreased compared to CC-SCC.

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