Structural Strengthening of Composite Beams Made with SCC and Cold Formed Steel Members

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Abstract - Concrete is one of the most widely used construction material in the construction industry throughout the globe. Many scientists and researchers are looking for a supplementary construction material that is eco-friendly and can contribute toward sustainable development. Composite sections which are made of concrete and cold formed steel sheets are extensively used in foreign countries to attain more structural proficiency. The structural strengthening of composite beams manufactured with Self compacting concrete and cold formed steel members are discussed in this article. CFS sheets of 2mm have been used to reduce the self-weight, thereby including additional tension reinforcement of 12mm diameter, which can take heavy loads and improve the structural efficacy. Cold formed steel sheets are used as trapezium shaped perforated sections for composite beam. The behavior of composite SCC beams raises the ultimate load carrying capacity and drops the ultimate mid span deflection for increasing the load and reducing the flexural crack widths, compared with control beam.

Index terms: Composite sections, Cold formed steel, Self-compacting concrete, Crack location, Crack width.

I. INTRODUCTION

Conventionally, reinforced concrete elements display some sort of deterioration in their performance on aging, because of poor resistance against unfavorable environmental conditions and integrated nature of materials. Furthermore, the rejuvenation of structures composed of such materials entails the use of heavy equipment, high power and skilled labor, which increase the overall cost. Hence the composite construction has become a more prevalent method and has largely accounted for the dominance of steel frames in many countries.

Composite beams are extensively used due to the reduction of steel cross sectional area, longer spans, greater stiffness, etc. Nowadays, SCC is an important improvement in the field of construction. Self-Compacting concrete was one of the high-performance materials in the field of construction, which offers various advantages such as the elimination of the need to use vibrators. It flows under its own weight can settle around the formwork when the density of reinforcement provided is more or if there is minimum spacing between the reinforcement bars. Through its vast advantages, all around the world number of investigations were made on SCC in the construction of high rise buildings and structural work. These investigations were mainly made in developed countries like USA, Canada, Japan, etc.

The construction industry of CFS sections has rapidly grown and has been recognized as key contributors to sustainable structures in the developed countries. In the construction of low rise buildings, CFS is considered as a sustainable 'green' construction material. The thickness of CFS sections ranges typically between 0.4mm and 6mm to a required shape either by press braking or by roll forming or bending brake operation (without application of heat).

II. LITERATURES REVIEWED

Recent studies of civil structures conducted by Teng and Lam have illustrated that most of the civil structures often need periodical maintenance, repairs and rehabilitation. The conservation of weakened steel structures has been a subject of concern for years to structural engineers. Principal causes of premature deterioration or distress pertaining to steel structures normally include the combination of incorrect design and variations in structural function. Likewise changes in loading or the deterioration of steel was discussed by Ong and Kang. Sanjay K. Behera studied the numerous vibration-based damage analysis techniques.

III. MATERIALS USED

In this study, the materials used for the manufacture of composite beams have been designated underneath.

- Nature of cement: OPC of 53 grade conforming to IS 268-1976
- Nature of concrete: Self compacting concrete
- Grade of concrete: M30
- Form of aggregate: 20mm size rounded coarse aggregate and fine aggregate passing through 4.75mmm sieve conforming to IS 383-1970.
- Type of reinforcement: 12mm dia HYSD bars as tension reinforcement
- Super plasticizer: SP430 and dosage of 2.5%
- Cold formed steel sheets of 2mm thickness

Mater ials	Cement	Fine aggregate	Coarse aggregate	Water
Weig ht in kg	524.31	874.62	687.2	220.21
Mix Propo rtion	1	1.67	1.31	0.42

Table 1: Concrete mix materials

IV. EXPERIMENTAL INVESTIGATION

Several tests were conducted in order to view the differences in the behavior of SCC in its fresh and hardened states as well as the structural behavior. The slump flow, V-

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funnel tests, T500, L-box, U-box tests are conducted for concrete during its fresh state and the hardened concrete tests for compressive strength, flexural strength and split tensile strength.

TABLE 2: FRESH PROPERTIES OF SCC

SCC Mix	Strength of SCC based on Curing period					
	7 days			28 days		
	Split Tensile Strength (N/mm^2)	**Compressive Strength (N/mm^2)**	**Flexural Strength (N/mm^2)**	**Split Tensile Strength (N/mm^2)**	**Compressive Strength (N/mm^2)**	**Flexural Strength (N/mm^2)**
1	2.54	30.5	5.76	3.11	42.0	6.24
2	2.39	30.0	6.04	3.26	41.0	6.31
3	2.39	28.5	6.21	2.93	39.0	6.84
Final Mix	2.31	25.5	6.48	3.61	42.5	7.25

TABLE 3: STRENGTH PROPERTIES OF SCC AT HARDENED STAGE

SCC mix	Slump flow (mm)	T500mm Slump flow (Sec)	V funnel test (Sec)	L Box test	U Box test
1	670	5	11	0.81	0.03
2	675	4.5	10	0.83	0.04
3	685	3.5	8	0.85	0.01
Final mix	700	4	9	0.88	0.02

Also, the flexural behavior of composite beam is tested under a two-point loading condition. All the beams were cast for the final mix design and w/c ratio of 0.42, achieving self-compaction without using vibrators. The beam specimens were cured in 14 &28 days and then tested. Size of beam cast was 150 x 200 x 2000 mm with cold formed steel sheets and 2 numbers of 12mm diameter rods are used at the compression zone.

Fig. 1: Experimental test setup for SCC composite beam

HEORETICAL ANALYSIS

The goal of structural design may be stated as the achievement of acceptable probabilities that the structure being designed will no longer become unfit for the use for which it is required during its proposed life. Indian standard of IS 11384is restricted only to buildings of composite construction. Based on the code, limit state method can be used to design a steel concrete composite structure.

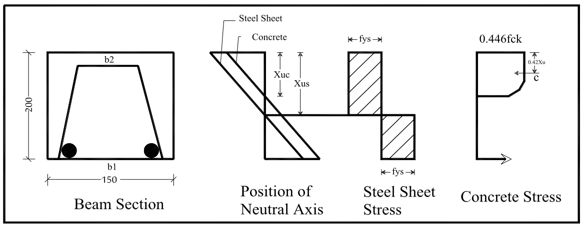

Fig. 2: Moment of resistance due to steel fabrication sheet and concrete

a. *FLEXURAL AND DEFLECTION BEHAVIOUR FOR SCC*

Four SCC mixtures of RCC beam specimens for M30 grade were prepared and tested for Flexural behaviour, Crack pattern and Surface strain. The flexural and deflection behavior test results are discussed below.

TABLE 4: BEHAVIOR OF COMPOSITE BEAM WITH SCC AND CFS UNDER TWO-POINT LOADING

Specimen	**Cracking Load (kN)**	**Deflection at First Crack (mm)**			**Ultimate Load (kN)**
		L/3	**L/2**	**L3**	
A1	23	1.31	1.61	1.42	72
A2	25	1.59	1.82	1.66	81
A3	25	1.88	1.93	1.87	87
A4	27	2.58	2.87	2.65	92
Specimen	**Cracking Load (kN)**	**Deflection at Ultimate Load (mm)**			**Mode of Failure**
		L/3	**L/2**	**L3**	
A1	23	10.51	12.22	10.78	Flexure
A2	25	12.36	14.36	11.79	Flexure
A3	25	12.94	14.83	12.54	Flexure
A4	27	15.89	18.63	16.43	Flexure

Figure 3: Cracking load and Ultimate load of composite beams

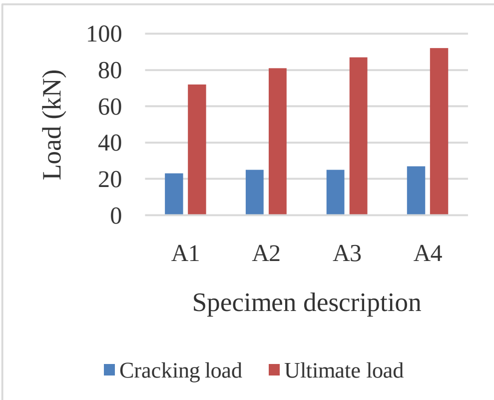

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TABLE 5: DEFLECTION BEHAVIOUR OF COMPOSITE BEAM WITH SCC AND CFS

S.No	Load (kN)	Mid span Deflection(mm)			
		A1	A2	A3	A4
1	0	0.00	0.00	0.00	0.00
2	1	0.30	0.17	0.26	0.31
3	6	1.63	0.89	0.55	0.56
4	9	2.35	1.31	1.08	0.95
5	23	2.97	1.82	1.93	1.54
6	25	4.10	2.34	2.45	2.26
8	27	4.67	2.88	2.81	2.87
7	33	5.06	3.16	3.35	3.31
8	39	5.91	3.61	3.70	4.09
9	45	6.32	3.97	4.12	4.69
10	49	6.63	4.22	4.46	4.91
11	54	6.69	4.46	4.71	5.26
12	58	7.55	4.90	4.95	5.40
13	62	8.53	5.20	5.39	5.63
14	64	9.48	5.56	5.73	5.82
15	67	10.57	6.15	6.34	6.45
16	69	11.48	8.01	7.43	7.21
17	72	12.22	9.60	9.46	8.71
18	76	-	11.07	10.85	9.62
19	79	-	12.54	12.24	10.91
20	81	-	14.37	13.78	13.21
21	84	-	-	14.17	14.86
22	87	-	-	14.95	15.61
23	92	-	-	-	18.63

V. COMPARISON OF RESULTS

The results of hand calculation analysis and experimental results are compared in table given below.

TABLE 6: FIRST CRACK AND ULTIMATE LOADS OF SCC COMPOSITE BEAMS IN FLEXURE

Specimen description	Cracking load P_{cr} (kN)	Cracking load P_u(kN)	P_{cr}/P_u(%)
A1	23	72	31.94
A2	25	81	30.86
A3	25	87	28.74
A4	27	92	29.35

TABLE 7: THEORETICAL AND EXPERIMENTAL MOMENT CARRYING CAPACITY COMPARISON

Type of beasm	Specimen description	Experimental moment capacity (kNm)	Theoretical moment carrying capacity (kNm)	Ratio of M_E/M_T	Average of -α
I	A1	12.35	9.25	1.33	1.41
	A2	13.65	9.25	1.48	
II	A3	15.28	12.34	1.24	1.31
	A4	16.90	12.34	1.37	

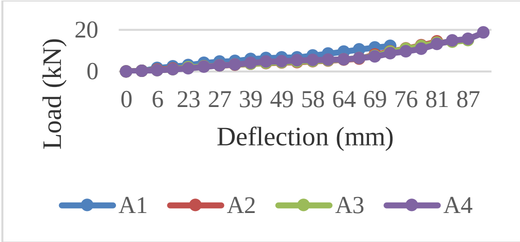

Fig. 4: Load vs deflection curve for Composite beams with SCC and CFS

VI. CONCLUSIONS

Following are the conclusions made after the investigation on composite beams made with self-compacting concrete and cold formed steel sheets.

- Self-compacting concrete shows acceptable performance in fresh state as per EFNARC guidelines.
- Higher ultimate loads are achieved for SCC beams strengthened with CFS sheets as compared with un-strengthened control beam.
- The ultimate load carrying capacity of SCC beams strengthened with CFS sheets increase by 27.78% compared to the control beam, and they fail due to flexure.
- Presence of tension reinforcement in SCC beams fails in flexure and decreases deflection at the same load level.
- Based on the experimental results, the strengthened SCC beams fail due to diagonal flexural cracks. These cracks are produced by poor bonding failure of all CFS sheets in flexural zone at ultimate load level.
- Experimental results show that the ultimate moment carrying capacity of strengthened SCC beams is 1.78 times higher than the theoretical results.
- SCC strengthened beams are steady and fail only due to yielding of steel and there is no unexpected failure of concrete.
- Addition of CFS sheets in control beams makes them a composite section and the overall deflection of the sections is reduced.

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