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NUMERICAL MODELING OF COMPOSITE BEAMS MADE WITH SELF COMPACTING CONCRETE

[1]S. Sathyan, [2]R. Sundararajan, [3]K. Vivek

[1,2]Karpagam Academy of Higher Education, Coimbatore, India. [3]Paavai Engineering College, Namakkal, India. Email: *sathyapranav@gmail.com,

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ABSTRACT

Concrete is a widely used building material; many scientists are in the hunt for forming an alternative material for construction that is environment-friendly, constantly available and offers sustainable development. Composite sections which are made with concrete and cold formed steel sheets are more widely used in foreigncountries to attain more structural efficiency. In this study,CFS sheets of 2mm are used to decrease the self-weight, thereby addingadditional tension reinforcement of 12mm diameter.It can take heavy loads andimprove the structural efficiency. Cold formed steel sheets were used as trapezium shaped perforated sections for composite beams.Therefore, cold formedsteel sections increase the load carrying capacity ofbeams by using self-compacting concrete of grade M30.

Keywords: Composite sections, Cold formed steel, Finite element modeling

I. INTRODUCTION

Traditionally, building materials like steel and concrete, display signs of rotting in their performance as they age. The rejuvenation of such structures composed of such elements entails the use of skilled labour andheavy equipment, which increases the overall cost. Hence the composite construction has become a more prevalent method and has primarily accounted for the dominance of steel frames in many countries. Composite beams are extensively used due to its reduction of steel cross-sectional area, longer spans, higher stiffness, etc. (Balasundaram and Paulraj, 2017).

Self-compacting concrete could be clarified as high-performance materials that can stream under its own weight, without application of external vibration, to attain consolidation by filling up form works, even if accessibility is constrained by slim openings between reinforcement bars.This technology is a vital solution in the construction industry, where mechanical vibration is not possible because of the complexity in formwork. Because of these advantages, investigations on SCC in civil industry has become popular throughout the world. (Sallam et al., 2013).

Cold-formed steel (CFS) structural members represent an essential component of modernized steel structures due to their strength to weight ratio. Generally, CFS members are produced with cold rolled thin sheets of thickness ranging up to 6mm.CFS structural members are more effective in industrial design than hot rolled members due to the dominant ease of fabrication and strength to weight ratio.

There are several methods for shaping the behavior of concrete structures by analytical and numerical methods. Finite Element Analysis Approach (FEA) is one of the numerical procedures which is implemented in concrete structures based on the nonlinear behavior of materials (ASTM-2000, Balasundaram et al (2017), EFNAR-2000, Sallam et al., (2013), Sousa et al., (2010), Pamnani Nanak et al (2013)).

II. **LITERATURES REVIEWED:** In the recent times, the demand of structural repair and rehabilitation had been illustrated by Teng and Lam. The major causes of deterioration among certain steel structural components includes wrong design aspects and its varying behavior. With the consideration of many researchers, the analytical prototype including their shear distribution as a part for the composite beams. (Sousa et al., 2010) The composite beams are mentionned by second order differential equations by generating stability and compatibility equation of each element. This prototype delivers the supply bond of steel and concrete interfaces projection. (Pamnani 2013). The load specification and the correction on the steel were discussed by Ong and Kang illustratively. Numerous kinds of research had been done on the attribute of composite beams on shear interaction as partial. Martinez and Ortiz describe the analytical solutions for the beams which are simply supported under simple loading case with the help of this differential equation method.

III. MATERIALS USED FOR SELF COMPACTING CONCRETE: In this study, the following materials were used in the preparation of Self-compacting concrete of grade M30. Cement used for all beams specimens was ordinary Portland cement of 53 grade confirming to IS 268-1976, the aggregates used for all specimens confirmed to IS 383-1970. 12mm diameter steel reinforcement was used as tension reinforcement. Cold-formed steel sheet of 2mm thickness was used to make the perforated fabricated sections. Super plasticizer of SP430 dosage was 2.5%.

Table 1: Mix design for SCC

Materials	Cement	Fine aggregate	Coarse aggregate	Water
Weight in kg	524.31	874.62	687.2	199.24
Proportion	1	1.67	1.31	0.38

Table 2: Properties of fresh self-compacting concrete

Trail mix	Slump flow (mm)	T50cm 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

Table 3: Properties of hardened self-compacting concrete

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

IV.FINITE ELEMENT MODELING: Finite element analysis on the composite beam sections were done by the software package ANSYS 12.0. The beams were modeled and tested either in APDL or GUI. The specimens were loaded under two-point loading conditions and non-linear buckling analysis was done to determine the characteristic of the sections. The correlation was done by comparing the predicted analytical results in ANSYS and with the experimental results. The following elements were adopted for material idealization.

Table 4: Description of used elements in ANSYS

Elements used from ANSYS library	Element Characteristics			Beam Components
	Number of nodes	Type of element	DOF per node	
SOLID65	8	Brick element	3 – T*	Concrete
SOLID45	8	Brick element	3 – T*	Bearing steel plate of loading
LINK8	2	Discrete element	3 – T*	Steel reinforcing bars (Tension reinforcement at bottom)
SHELL181	4	Shell element	3 – T* & 3 - R**	Cold formed steel section

T* - Translational Degree of Freedom; R** - Rotational Degrees of Freedom

Modeling a structural element for the behavior of composite sections made with self-compacting concrete was a difficult task. The properties of concrete were found based on the guidelines of IS456:2000. Coupon test on CFS sheets was used to determine the material properties of steel sheets used in this study. As per American Standards for Testing Materials (ASTM) 370 – 03A, the test procedure and dimension of test specimen was followed in the Coupon test.

Table 5: Material properties for SOLID65 element

S. No.	Definition	Value
1	Young's modulus of elasticity	31185MPa
2	Poisson's ratio	0.2
3	Characteristic compressive strength	30MPa
4	Density	2380kg/m^3
5	Ultimate compressive strength	42.5MPa
6	Ultimate tensile strength	3.26MPa
7	Shear transfer parameter	0.2 to 0.7

Table 6: Material properties for SOLID45 element

S. No.	Definition	Value
1	Young's modulus of elasticity	2 x 10^5MPa
2	Poisson's ratio	0.3

Table 7: Material properties for LINK8 element

S. No.	Definition	Value
1	Young's modulus of elasticity	2 x 10^5MPa
2	Poisson's ratio	0.3
3	Yield stress	415MPa

Table 8: Material properties for SHELL181 element

S. No.	Definition	Value
1	Young's modulus of elasticity	2 x 10^5MPa
2	Poisson's ratio	0.3
3	Yield stress	250MPa
4	Thickness	2mm
5	Tangent modulus	2 x 10^4MPa

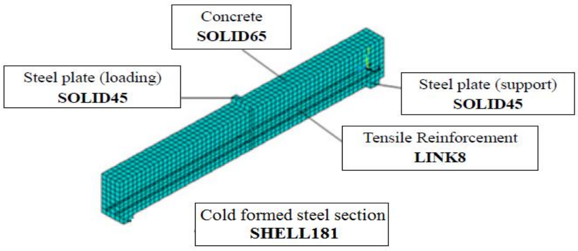

Fig. 1: Element types of ANSYS modeling

V. EXPERIMENTAL INVESTIGATION

All the beams were cast for the final mix design and the water-cement ratio of 0.42. Thus self-compaction achieved without any vibrators. The beam specimens were cured in 14 & 28 days and then tested. Size of beam cast was 150 x 200 x 2000mm with cold-formed steel sheets, and two numbers of 12mm diameter rods are used at the bottom. The aim of structural design may be to achieve acceptable probabilities that the structure can be designed to be fit for its use during its intended life.

Fig. 2: Experimental test setup for SCC composite beam

VI. COMPARISON OF RESULTS

The structural behavior from the FEA ANS-YS and the theoretical results are similar to each other. Comparison of theoretical, experimental and finite element approach was tabulated below.

Table 9: Comparison of moment carrying capacity

S. No.	Type of beam	Specimen number	Moment carrying capacity (kNm)			M_{Exp}/M_{Th}	M_{FEA}/M_{Th}
			Theoretical	FEA	Experimental		
1	I	A1	7.39	8.71	8.28	1.12	1.18
		A2	7.39	7.88	7.38	1.00	1.07
2	II	A3	12.32	13.28	12.6	1.02	1.08
		A4	12.32	13.59	12.96	1.05	1.10
Standard deviation						0.053	0.050

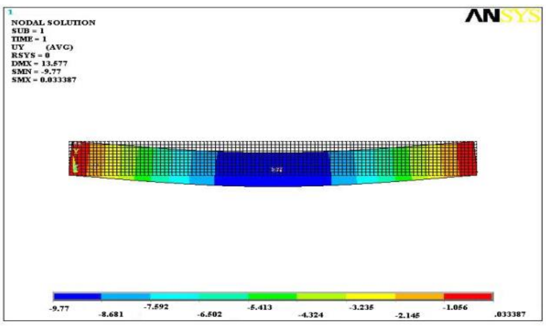

Fig. 3: Deflection behavior of Composite beam with SCC

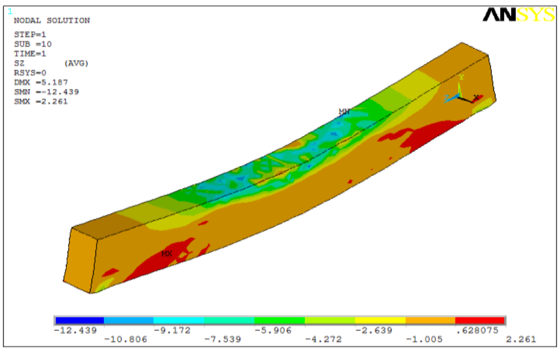

Fig. 4: Stress contour for composite beam with SCC

VII. CONCLUSION

Following are the conclusions made after the investigation on composite beams made with self-compacting concrete.

- All the SCC mixes have a satisfactory performance in the fresh state
- Numerical analysis results mostly coincide with the theoretical and experimental results.
- The initial cracking does not affect failure load.
- The standard deviation for both ratios of MExp/MTh and MFEA/MTh is almost equal.
- The experimental ultimate moment carrying is more than 1.8 times than the theoretical ultimate moment carrying capacity.
- There is no sudden occurrence of concrete and failure, which is rather gradual due to yielding of steel which is preferred for safety mode of failure.
- Deflection behavior of the beam is improved by the addition of cold-formed steel sheets in the beam.

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