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Fracture Mechanics based Analysis of Self Compacting Concrete with Steel Fibers using Finite Element Modelling

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Abstract *—Self-compacting concrete is a highly-workable concrete. It compacts under its own weight without any vibration or impact; While, Fiber reinforced concrete (FRC) is a concrete in which small and discontinuous fibers are spread uniformly. The addition of fibers into concrete mass can dramatically change properties of concrete. The finite element modeling and analysis of Self Compacting Concrete beam subjected to three point bending load is done in ANSYS Workbench 17.2.*
This paper analyzed the effect of fiber addition on rheological properties and fracture energy of self compacting concrete. Rheological properties like J Ring, U Box, L Box are determined as per EFNARC standards. Fracture energy (G_F) measured using the three-point bending test on pre-notched beams prescribed by RILEM recommendations. Grade of concrete used is M40 for the beam. The beam is of overall dimension of 430×150×100 mm. The beam is studied for the ultimate load, load-deflection and load-strain behaviour for this case and compared with the experimental values.
The result shows that workability of SCC decreases with addition of fibers but fracture energy increases with addition of fibers in self compacting concrete. The study also indicates that finite element modeling is properly able to simulate the behaviour and fracture properties of SCC beam under flexure. The Comparison study shows that the FEA predicts a 10% variation in the deflection studies.

Keywords*- SCC, SSFRSCC, HSFRSCC, RCSFRSCC, FEM, ANSYS17.2, Fracture Toughness Test*

I. INTRODUCTION

- ✓ In history, a lot of disasters cause by fracture failure of structures had caused many injuries and financial loss. Overall cost of facture in U.S.A in 1978 was estimated to $119 billion or 4% of the national product, the annual cost could be reduced by $35 billion if current technology were applied and could be reduced additional by $28 billion, if further reached was implemented. During the World War II, the Liberty ships was produced with revolutionary procedure for fabricating ships quickly by an all-welded hull, where it normally was joined by riveted.
- ✓ After this fracture failure, the mechanics of fracture become an engineering issue, standards and procedure for inspections was conducted. One of the leading researchers in this area was Dr. G.R. Irwin after studying the early works of Inglis, Griffith, Westergaard and others scientists, he explore some of the todays tools for fracture mechanics. Today Irwin is called one of the “fathers” of fracture mechanics.
- ✓ In this paper, Numerical solutions are conducted in ANSYS Workbench 17.2, and a process of programming to obtain generals numerical solutions for fracture behavior and fracture properties are accomplished. In order to verify the numerical solutions, experimental results are also taken.
- ✓

II. WORK PLAN

Table 1. Number of cubes, beams & cylinders

	Compression test		Splitting tensile strength	Fracture Test
	Cubes for 7 days	**Cubes for 28 days**	**Cylinders for 7 days**	**After 28 days**
SCC	3	3	3	3
SSFRSCC	3	3	3	3
HSFRSCC	3	3	3	3
RCSFRSCC	3	3	3	3
Total	*12*	*12*	*12*	*12*

2.1 Materials

- ✓ The cementitious materials used in all mixtures are commercially available Ordinary Portland Cement (OPC) of 53 grade confirming to IS: 12269. The specific gravity of the cement is 3.13. Locally available river sand passing through 4.75 mm IS sieve is used. The physical properties of the fine aggregates like specific gravity and bulk density is of 2.67 and 1868 kg/m3 respectively. Coarse aggregates maximum sizes 40 mm are used for the investigation. The coarse aggregate, obtained from a local source, has a specific gravity and bulk density is of 2.84 and 1652 kg/m3 respectively.

- ✓ The ***fly ash*** used in the investigation is procured from Kakatiya Thermal Power Station. This is collected from electrostatic precipitator. The specific gravity of fly ash is found to be 1.95.High range water reducing admixture called as ***super plasticizers*** are used for improving the flow or workability for decreased water cement ratio without sacrifice in the compressive strength. In the present work water-reducing admixture ***Glenium B233*** conforming to ASTM C494 types F is used. Three types of ***steel fibers*** trade name of Stewols India Pvt, Ltd, are used in this study. The steel fibers are relatively stiff and water-soluble, glued into bundles.

2.2 Mix Design

- ✓ Cement = 344.64 kg/m^3
- ✓ Water = 189.55 kg/m^3
- ✓ Fine aggregates = 1015.59 kg/m^3
- ✓ Coarse aggregates = 744.12 kg/m^3
- ✓ Fly ash = 3.70 kg/m^3
- ✓ Water for fly ash = 1.67 lit/m^3
- ✓ Super plasticizer = 3.48 lit/m^3
- ✓ Adjustment of water quantity = 189.13 kg/m^3
- ✓ W/C = 0.55, Water / Fly ash = 0.45, Air content = 1.5%

III. EXPERIMENTAL ANALYSIS

3.1 Assessment of Fresh State Concrete Properties

- ✓ To evaluate workability of fresh self compacting concrete like filling ability, passing ability and segregation resistance, different test were carried out as per EFNARC standards. Filling ability of SCC was measured using slump flow and V – funnel test. Passing ability of SCC was measured using J- ring, L- box and U – box test. Test results shows that, addition fibers reduce the flow and filling ability. Additions of Hooked steel fibers resist flow of SCC compared to other steel fibers. Also, L Box and U Box test results shows that additions of fibers in concrete give negative result on workability of SCC. But all results are within limit of EFNARC.Test results are shown in table 2.

Table 2: fresh state concrete properties

Mix	**Slump Flow (mm)**	**T_{50} cm slump flow (sec)**	**J Ring**	**J Ring flow (mm)**	**V Funnel flow (sec)**	**L box blocking ratio**	**U box filling height (mm)**
EFNARC limit	*650 – 800*	*2-5*	*0-10*		*6-12*	*0.8-1*	*0-30*
SCC	760	4.2	6	730	8	0.93	20
SSFRSCC*	730	4.4	9	710	10	0.89	23
HSFRSCC*	755	4.9	10	650	12	0.80	27
RCSFRSCC*	745	4.6	9	690	11	0.86	26

3.2 Mechanial properties

- ✓ After casting cubes, cylinders and flexural beams, specimens are tested as per IS 516. Results of compression & split tensile test are presented in Table 3.Fiber addition increased indirect tensile strength in concretes.The best performance was obtained with the hooked steel fibers that showed the best results, which was probably due to the anchorage of the fibers and the higher modulus of elasticity of the material itself. Moreover, the addition of glass fiber also increased tensile strength.

Table 3: Mechanical properties

Mix	**After 28 days (N/mm^2)**	
	Compressive Strength	**Split tensile strength**
SCC	54.19	3.00
SSFRSCC	55.23	3.12
HSFRSCC	56.78	3.45
RCSFRSCC	55.90	3.30

3.3 Fracture test

Figure 1: Fracture test setup

- ✓ In accordance with the RILEM Technical Committee 89- FMT on fracture mechanics of concrete, specimens are prepared and three-point bending tests were carried out in three prismatic specimens of each concrete type with dimensions 431 ×152 × 100 mm3 to understand effect of fibers addition on fracture energy.

Table 4: Peak load, displacement & CMOD

Detail	SCC	SSFRSCC	HSFRSCC	RCSFRSCC
Peak load (kN)	6.68	6.78	6.97	6.85
Displacement at peak (mm)	0.43	0.45	0.47	0.46
Displacement (mm)	1.21	3.32	4.00	3.87
CMOD (mm)	1.72	5.89	6.40	6.20

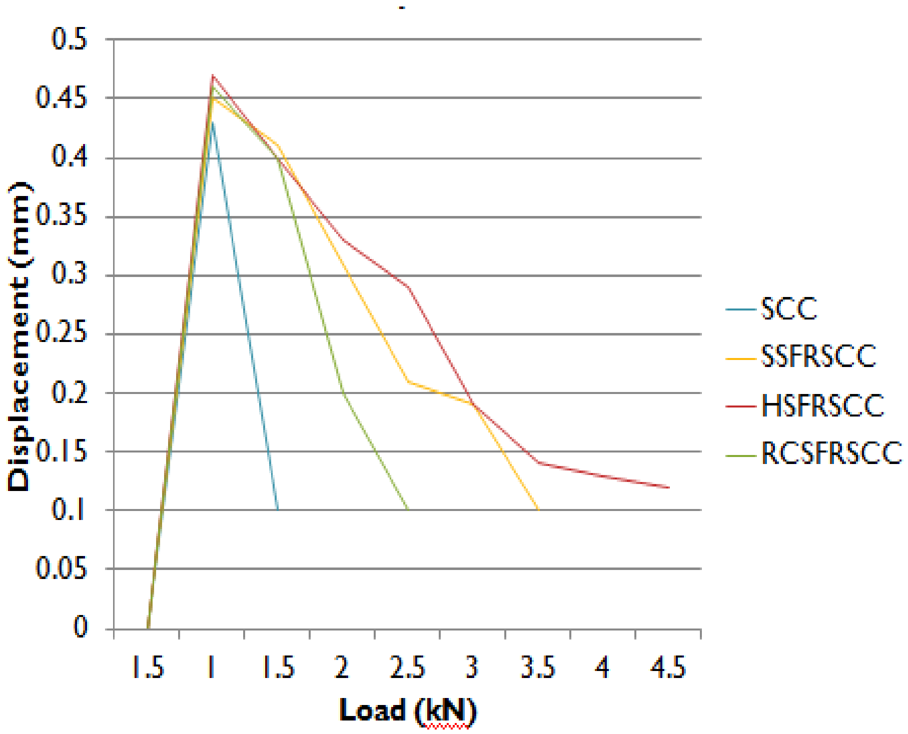

Figure 2: Load vs. displacement

IV. ANALYTICAL ANALYSIS

- ✓ Numerical analysis of crack propagation is carried out in ANSYS, where a code have been programmed in ANSYS Parametric Design Language (APDL), determining the Displacement using fracture test and also finding out the fracture properties like stress intensity factor & J integral. In Figure 3, a schematic diagram for the whole ANSYS process is shown.

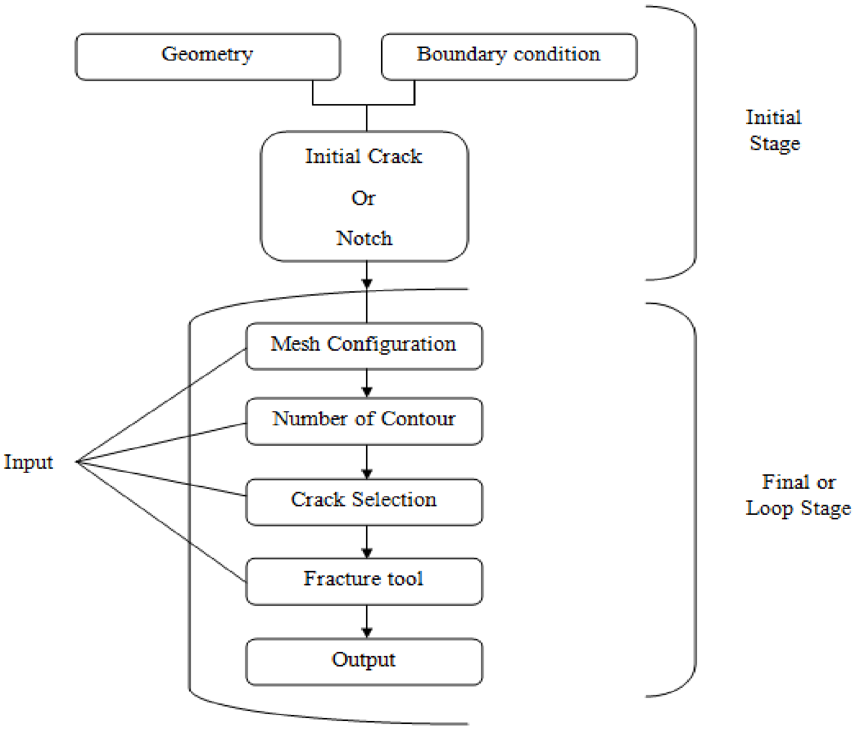

Figure 3: ANSYS Process

4.1 Modified GUI Menu

- ✓ In ANSYS three control files arrange the menu- and functions files for the whole GUI menu. In order to implementing the APDL code in the GUI, a user defined control file has been created to modify the GUI menu. In Figure 5.21 a diagram shows the configuration of this file, with the use of control file, menu- and function blocks, and the APDL codes.

4.2 Modelling

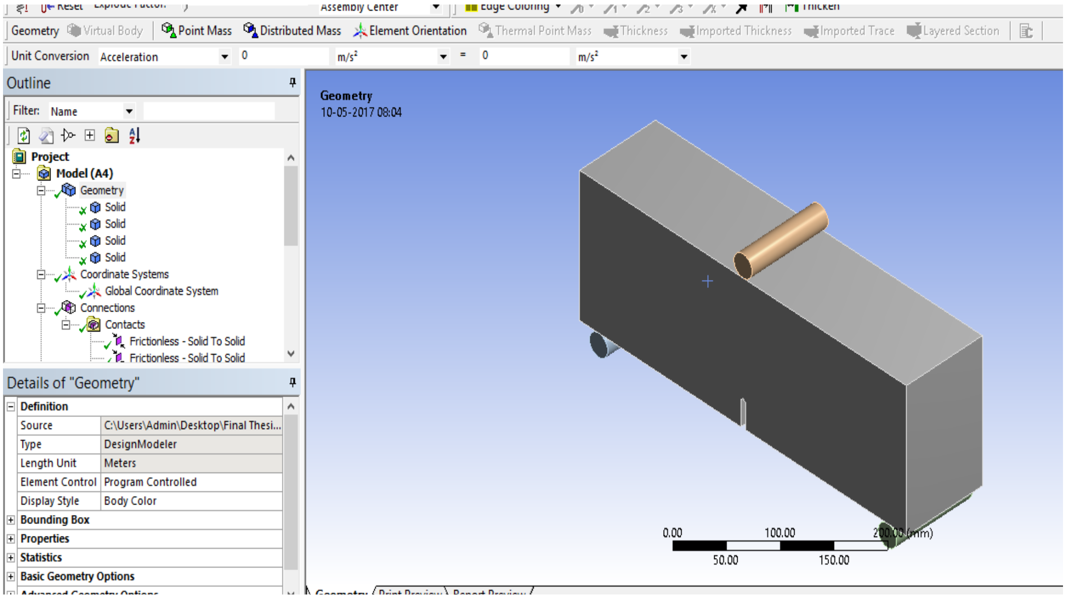

Figure 4: Geometry

4.3 Results

- ✓ After the geometry and mesh configuration process, the boundary conditions are applied. And then fracture tool is applied at the crack tip on pre mashed crack. After applying for the force vs. displacement curve and fracture parameters like stress intensity factor and J integral the Solution process is carried out.

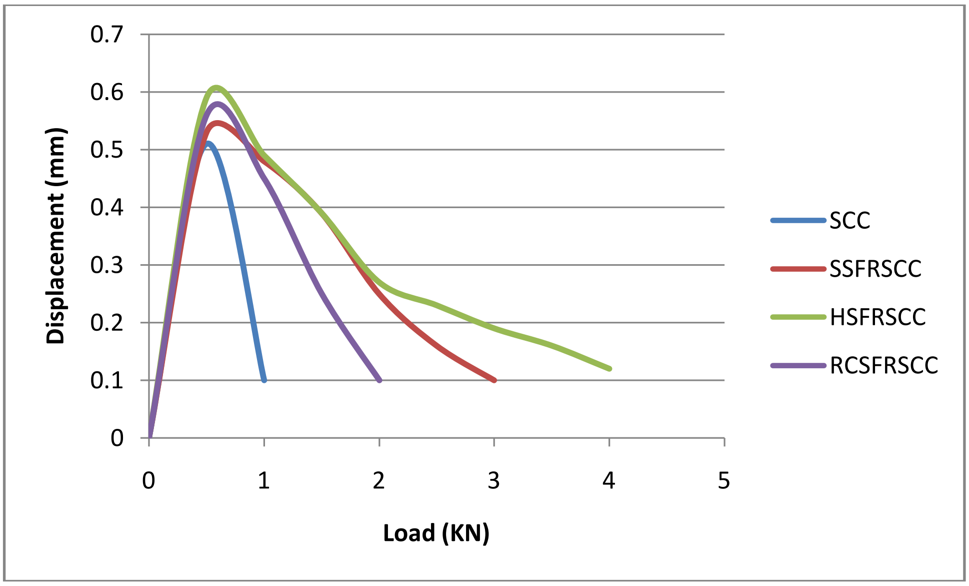

Figure 5: Load vs. displacement by analytical method

V. CONCLUSIONS

- ✓ The inclusion of fibers has a direct effect on the flow characteristics of SCC. Addition of fibers decreases the workability of the SCC.
- ✓ Concrete with hooked steel fibers has less workability compared to other fiber reinforced concrete.
- ✓ The results revealed that the addition of fiber reduces the passing ability and increase the possibility of blockage.
- ✓ Fibers lead nominal increase in compressive strength but marginal increase in spilt tensile strength and flexural strength of self compacting concrete.
- ✓ Addition of steel fibers to concrete significantly improves the tensile and flexural strength of concrete and produces strain hardening material.
- ✓ There is slightly increased in peak load but total displacement, crack opening at failure and area under load displacement curve increased tremendously with addition of fibers.
- ✓ Present numerical procedure may be used to predict fracture properties for different SCC beams with fibers.
- ✓ Numerical results have good agreement with experimental results and respectively with Eurocod's recommendations.
- ✓ The Comparison study shows that the FEA predicts an 8 - 10% variation in the displacement studies while there is 10 -12% variation in the fracture parameters.
- ✓ More calculations are necessary for beams with other shear span ratios, reinforcement ratios etc.

REFERENCES

[1] T. L. Anderson, "Fracture Mechanics", Fundamentals and Applications, 2005.

[2] R. I. Stephens, A. Fatemi, R. R. Stephens og H. O. Fuchs, "Metal Fatigue in Engineering", 2001.

[3] A. Sreenivasa Rao and G. Appa Rao, "Fracture Mechanics of Fiber Reinforced Concrete: An Overview", International Journal of Engineering Innovation & Research Volume 3, Issue 4, ISSN: 2277 – 5668.

[4] W.-J. Kim, M.-S. Kwak & J.-C. Lee Kyungpook, "Fracture properties of high-strength steel fiber concrete", National University,Korea, 2012.

[5] Nabil A. B. Yehia, Noran M. Wahab, "Fracture Mechanics of Flanges Reinforced Concrete Sections", Engineering Structures, 2007.

[6] B. G. Patel, A. K. Desai, S. G. Shah, "Fracture Properties of Fiber Reinforced Self Compacting Concrete Notched Beams", International Journal of Advance Research in Engineering, Science & Technology(IJAREST), ISSN(O):2393-9877, ISSN(P): 2394-2444, Volume 2,Issue 11, November-2015.

[7] Lecturer Algirdas Augonis, Professor Antanas Žiliukas, "Research on Fracture of Fiber Reinforced Concrete subjected to Combined Stress", International Journal of Education and Research - April 2014.

[8] Awoyera, P. Oluwaseun, "Nonlinear finite element analysis of steel fibre- reinforced concrete beam under static loading", Journal of Engineering Science and Technology – April 2011.
[9] Paola Costanza Migliatta, Geovanni Graselli, Evan C. Bentz, "Finite/ Discrete element model of tension stiffening in GFRP reinforced concrete", Science Direct – 2016.
[10] A. Simone, L.J. S, F.KF. Radtke, "A computational model for failure analysis of fiber reinforced concrete with discrete treatment of fibers", Science Direct – 2009.
[11] Xiaodan Ren, Jie Li, "Multi scale based fracture and damage analysis of steel fiber reinforced concrete", Science direct – February 2013.
[12] Fu Ming Lin,Yih Yuan Jan, "Non linear finite element analysis of reinforced concrete beams strengthened by fiber reinforced plastics", Scince Direct 2011.
[13] Pradeep singh, Abhishek Mishra, Arpit Kulshreshtha, "Finite element analysis of reinforced concrete beam using ansys", International Journal of Education and Research - 2013.
[14] Yuan Geo, Christopher K. Y. Leyung, Jun Zhang, "Simulation of crack propagation of fiber reinforced cementitious composite under direct tension", Science Direct – 2012.
[15] Yoshinori kitsutaka, "Fracture mechanics based bending failure analysis for fiber reinforced light-weight concrete panel considering crack dispersion effect", 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 Paper No. 7009.
[16] Faisal fouad wafa, Associate Professor, "Properties and Applications of Fiber Reinforced Concrete" Science Direct - 2009
[17] Sabrina Vantadori, Andrea Carpinteri, Cammila Ronchei, Daniela Scorza, "Mode I Fracture toughness of fiber reinforced concrete by means of a modified version of the two- parameter model", 21st European Conference on Fracture, ECF21, 20-24 June 2016, Catania, Italy.
[18] M. C. M. Fernando , E. T. Moyer og H. Liebowitz, »A Near Optimal Crack Tip Mesh,« Pergamon, 1995.