Structural Analysis of a Fibre Reinforced Flexible Deep Beam

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Abstract **- The fiber reinforced concrete has been one of the top most innovations in concrete technology, highlighting improved structural integrity of the structure, by providing short discrete fibers, distributed uniformly and oriented randomly. Engineered Cementitious Composite, also known as bendable or flexible concrete is yet another fascinating innovation that accounts for drastic development in crack resistance in the structure and providing bendable nature to the member without failure. In this study, finite element analysis of Fiber Reinforced Flexible Concrete deep beam is carried out in ANSYS for cracking pattern, and is compared with the results for a Reinforced Cement Concrete deep beam. It has been observed that the crack resistance of FR Flexible concrete is much higher than that of reinforced cement concrete.**

Keywords - structural analysis, fiber reinforced, flexible, deep beam

I. INTRODUCTION

It has become an integral part of the industry. This is because of its high load bearing capacity. It is known for its capacity to take compressive loads, while the main drawback of conventional concrete is that it cannot take much tensile stresses. It fails under the tensile load. This problem can be resolved by the substitution of conventional concrete with flexible concrete. It is a special type of concrete that can take the bending stresses due to its flexibility, induced by special type of materials. It was developed by the Professor Victor Li at the University of Michigan. Its engineering name is Engineered Cementitious Composite (ECC). It exhibits the property of a ductile material instead of a brittle material which is shown by the conventional concrete.

Fig.1.An ECC model developed by Professor Victor Li

A. Objective of Study

Deep beam is a structural member that is in use for numerous mega structures. Flexible concrete being an innovative substitute to curb the tensile strength inadequacy of conventional concrete can be introduced in the construction of high rise structures requiring high strength and resistance.

Both being crucial elements in advanced construction technology, it is significant to analyze the performance of a flexible deep beam with fibre reinforcement.

In this study, the cracking pattern in a fibre reinforced flexible concrete deep beam is obtained by performing finite element analysis in ANSYS which is compared to RC beam.

II. FLEXIBLE CONCRETE

A. Materials

For giving the concrete flexibility we have to alter the material of the conventional concrete. In the flexible concrete coarse aggregate is replaced by fibers like silica fibers, glass fibers, steel fibers, asbestos fibers, polyvinyl alcohol fibers, etc. These micro fibers provide the flexibility to the concrete. It also act as a reinforcement material in the concrete.

Fig.2.Steel Fibers used in ECC

Additionally, the anti-frictional coating is provided so that the fibers particles can slide over one another and does not have the friction which may result into the cracks in concrete. This tendency of fibers to slip over one another, helps the concrete to minimize the crack and provide flexibility to the concrete. The normal cement can be used for the concrete.

The fine silica sand is suitable for the flexible concrete which is used in the water treatment plant but if it is not available the normal sand can be used but it may effects the strength and flexibility of concrete.

B. Engineering Properties

ECC or Engineered Cementitious Composites are mortars reinforced with typically 2 per cent by volume fibres to endure 3 to 7 per cent tensile strain without breaking or loss of strength [1].

The fibres are covered with a nanometre thick coating that allows them to slip when the material overloads, so that fabrications can be made to bend substantially instead of fracturing.

Stress strain curves of the finished composites show a similar appearance to those normally associated with hard metals rather than ceramics. Typical bend strengths are in the range 10 to 15MPa. Compressive strengths are up to 70MPa. During strain hardening, multiple micro-cracks, no more than 60 microns wide, form along the length of tensile specimens. The material is optimised to attain 500 times the strain capacity of normal types of concrete [6].

The flexible concrete has a very good self-healing property as it can heal the micro-cracks itself by the reaction of carbon dioxide and water. The flexible concrete is 30-40 % lighter than the conventional concrete. It requires less curing time, repair and maintenance, and are much more earthquake resistant due to its flexibility.

III. DEEP BEAM

Deep beams are structural elements loaded as simple beams in which a significant amount of the load is carried to the supports by a compression force combining the load and the reaction. As a result, the strain distribution is no longer considered linear, and the shear deformations become significant when compared to pure flexure.

Floor slabs under horizontal load, short span beams carrying heavy loads etc are examples of deep beams. Deep beam is a beam having large depth/thickness ratio and shear span depth ratio less than 2.5for concentrated load and less than 5.0 for distributed load. Because the geometry of deep beams, their behaviour is different with slender beam or intermediate beam.

Deep beams play a very significant role in design of mega and as well as small structures. Some times for architectural purposes buildings are designed without using any column for a very large span. In such case if ordinary beams are provided they can cause failure such as flexural failure.

IV. FINITE ELEMENT ANALYSIS

The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. ANSYS software is a powerful and flexible general-purpose finite element analysis and computational fluid dynamics package used for civil engineering.

A. Material Parameters

In this study, two different fibre-reinforced deep beam models, one of conventional Cement Concrete (CC) and the other of Engineered Cementitious Concrete (ECC) are modelled, both of grade M40 are modelled. The mix proportions and engineering properties of both CC and ECC are shown in Table. I, [2]

TABLE.I. MIX PROPORTIONS FOR CC AND ECC

Mix	Cement	Sand	Course Aggr.	Fly Ash	Fibre (Recron)	Water
CC M40	1	2.5	3.6	-	-	0.4
ECC M40	1	0.44	-	1	0.04	1

TABLE.II. MIX PROPORTIONS FOR CC AND ECC

Engineering Properties(MPa)	CC	ECC
Modulus of Elasticity	37000	39486.28
Flexural Strength	4.6	8
Split Tensile	4.52	4.62
Compressive strength	41.9	42.6
Poisson's Ratio	0.18	0.2
Density (kg/m^3)	2300	1600

The materials are modeled with their moduli of elasticity, densities and Poisson's ratios.

B. Cross-Section Details

The deep beam is modeled with a span of 850mm, of which 650mm is the clear span. The cross-section of the beam is fixed as 450mm deep and 150mm wide.

The main longitudinal reinforcement provided is of HYSD bars of diameter 18mm; minimum shear reinforcement provided is of 2 legged mild steel stirrups of 8mm diameter. The steel fibres provided are 50mm long and 1mm diameter fibres. The modulus of elasticity of steel is provided as 2x10^{5}MPa and Poisson's ratio as 0.3

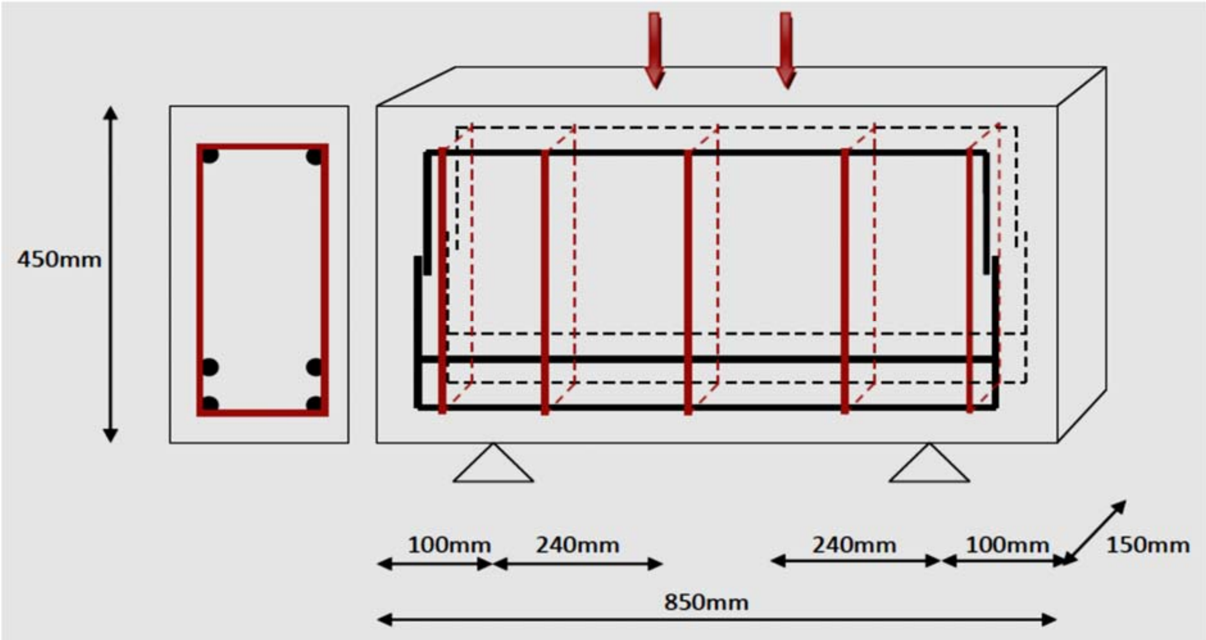

Fig.3. Deep beam section details being modeled as CC and ECC of M40 grade.

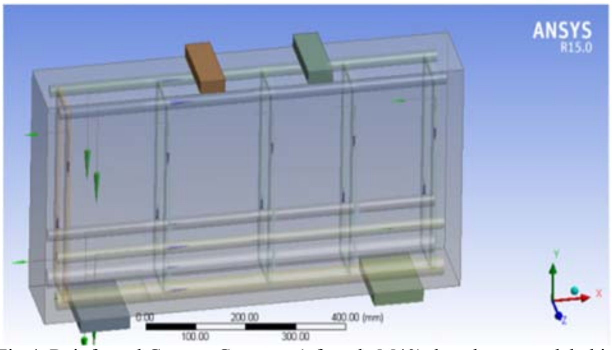

Fig.4. Reinforced Cement Concrete (of grade M40) deep beam modeled in ANSYS R15.0

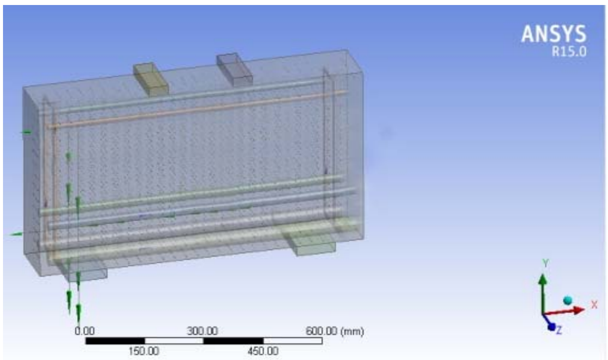

Fig.5. Fibre Reinforced Engineered Cementitious Composite (of grade M40) deep beam modeled in ANSYS R15.0

Both the models were subjected to two point loading up to fracture at 136kN, and the crack patterns were obtained as in Fig.6 and Fig.7.

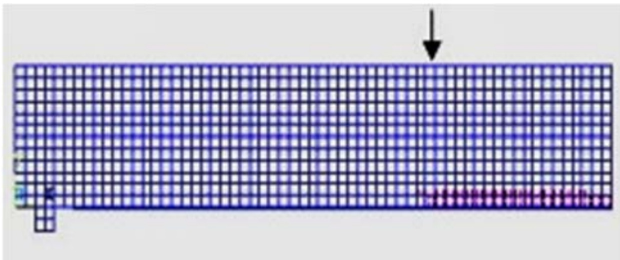
Fig.6. Crack simulation in ECC deep beam in half the span

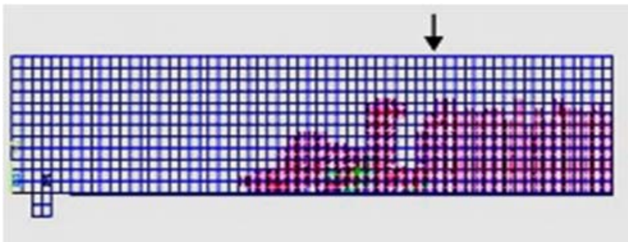
Fig.7. Crack simulation in RC Deep beam in half the span

V. RESULTS AND CONCLUSIONS

In the analysis of deep beams in reinforced concrete and fiber-reinforced flexible concrete (ECC) subject to cracking under flexural two point loading, it was observed that the cracks simulated in ECC at the same fracture load for RC deep beam was quite insignificant, while it became a major mode of failure in RC beam.

However, as far as ECC is concerned, cracking always accounts to micro-cracks which is self-healed by carbonation and hydration at the crack surface, increasing the service life of the structure and reducing maintenance expenses [5].

Also, in case of seismic loading, the ductile nature of load bearing members resists shear cracking, thereby making the structure safe from collapse

High rise structures requiring a great amount of flexural strength will find the use of ECC advantageous, as it gives high crack resistance to structures, even in heavily loaded members.

Moreover, with the use of fiber reinforcements, a great amount of reinforcement material can be saved, making the structure light and cost effective.

REFERENCES

[1] AlokRanjan, ShriramChaurasia, "Fibre Reinforced Bendable Concrete", IJSRD, vol. 5, Issue 1, pp. 376-378, 2017

[2] Anu T Eldo, DivyaSasi. "Determination of relationship between Mechanical Properties of ECC", IJISET, vol. 3, Issue 8, August 2016

[3] Balaguru, P.N. and S.P. Shah, "Fiber-reinforced cement composites", 1992

[4] KallepalliBinduMadhavi, Mandala Venugopal, v Rajesh and Kunchepu Suresh, "Experimental Study on Bendable Concrete", IJERT, vol. 5, Issue 10, pp. 501-504, October 2016.

[5] Li, V.C., "Engineered Cementitious Composites (Ecc)–Tailored Composites Through Micromechanical Modeling Micromechanical", T.C.T., 1998.

[6] Li, V.C., "Engineered Cementitious Composites (ECC) Material, Structural, and Durability Performance", 2008

[7] Zhang, J. and V.C. Li, "Monotonic and fatigue performance in bending of fiber reinforced engineered cementitious composite in overlay system", Cement and Concrete Research, 2002. 32(3): p. 415-423.

[8] Lin, Z. and V.C. Li, "Crack bridging in fiber reinforced cementitious composites with slip-hardening interfaces", Journal of the Mechanics and Physics of Solids, 1997. 45(5): p. 763-787.

[9] Li, V.C., S. Wang, and C. Wu, "Tensile strain-hardening behavior of polyvinyl alcohol engineered cementitious composite (PVA-ECC)", ACI materials Journal, 2001. 98(6).

[10] Li, V.C., "Engineered Cementitious Composites - Tailored Composites Through Micromechanical Modeling Fiber Reinforced Concrete: Present and the Future edited by N. Banthia, in Fiber Reinforced Concrete: Present and the Future edited by N. Banthia, A. Bentur, A. and A. Mufti", Canadian Society for Civil Engineering, Montreal, 1998: p. 64-97.

[11] A. W. Dhawale, Mrs. V. P. Joshi "Engineered Cementitious Composites for Structural Applications", International journal of application or innovation in engineering and management Volume 2, Issue 4, April

[12] Victor C. Li, and Gregory Keoleian "Development Of Green Engineered Cementitious Composites For Sustainable Infrastructure Systems" International Workshop on Sustainable Development and Concrete Technology, pg 181-191,2003

[13] Mathu P Sasi and Shibi Varghese "Investigation on Rheology Fibre dispersion androbust properties of ECC" Transactions on Engineering and Sciences Vol.2, Issue 11, November 2014

[14] Patel U. R., Rathod J. D, Chauhan D. K. " Comparative study of Engineered Cementitious Composites & Self compacting Engineered Cementitious Composites on Response under Impact Loading" International Journal of Emerging Technology and Advanced Engineering, Gujara,t Volume 2, Issue 2, February 2012

[15] J.D. Rathod "Comparative Study of the Steel and Polyester Fibre Reinforced Composite under Impact Load" Asian Resonance Vol.-III, Issue-I, January-2014

[16] Moreno DM, Trono W, Jen G, Ostertag C, Billington SL "Tension stiffening in reinforced high performance fiber reinforced cement-based composites", Cement Concrete Comp 50:36–46, 2014

[17] Yuan F, Pan J, Dong L, Leung CKY "Mechanical behaviors of steel reinforced ECC or ECC/concrete Composite beams under Reversed cyclic loading", J Mater Civil Eng 26(8):1–8, 2013

[18] Carol, I., P. Prat, and C. López, "Normal/shear cracking model: Application to discrete crack analysis", Journal of Engineering Mechanics 123(8), 765–773., 1997.

[19] Li, V. and C. Leung, "Steady state and multiple cracking of short random fiber composites", ASCE J. Eng. Mech. 188, 2246–2264., 1992

[20] Han, T., P. H. Feenstra, and S. L. Billington, "Simulation of highly ductile fiber-rienforced cement-based composite components under cyclic loading", ACI Structural Journal 100(6), 749–757., 2003.

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