FLEXURAL BEHAVIOUR OF SELF COMPACTING CONCRETE HOLLOW BEAMS REINFORCED WITH HYBRID FIBERS

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Abstract

The performance of conventional concrete is enriched by the addition of fibres in concrete. The brittleness in concrete is reduced and the acceptable ductility of concrete is ensured by the addition of fibres in concrete. In this study, the strength of concrete cubes, cylinders and beams cast using M25 grade concrete and reinforced with steel and polypropylene fibres are presented. Also, hybrid fibres with crimped steel and polypropylene were used in concrete matrix to study its improvements in strength properties of steel, polypropylene and hybrid steel (crimped) polypropylene and fibres of various proportion i.e., 0.25%, 0.5%, 0.75%, 1% and 0.5 % (0.25% of steel and 0.25% polypropylene), 0.75% (0.5% of steel and 0.25% polypropylene, 0.25% of steel and 0.5% polypropylene) and 1% of various combinations of hybrid fibres for 7,14 and 28 days respectively. The study of conventional flexural beam theory was replaced with the analysis structure, with the help of technology further it enhanced better understanding.

Keywords: *hybrid fibres, conventional concrete, flexural beam.*

Introduction

The development of Self Compacting Concrete (SCC) by Professor Hajme Okamura and K. Ozawa in 1986 has made an amazing impression on the construction industry by overcoming some of the complications associated with concrete in plastic stage. The SCC in plastic stage addresses many complications associated with the skill of workers, the complexity of reinforcement, type and shape of structural section, pumpability, segregation resistance and, more particularly, compaction. The Self Compacting Concrete, which contains more fines content, is proved to be more durable. Started in Japan, numbers of investigations were reported worldwide on the mix design of SCC, its microstructure and durability aspects. The composition of Self Compacting Concrete is same of normal concrete, that is, cement, fine and coarse aggregates, water, mineral and chemical admixtures. The notable difference of SCC from normal concrete is that the SCC contained a high dosage of powder, as well as a high dosage of high range water reducing agents (Super Plasticizers (SP)) and Viscosity Modifying Agents (VHA) to ensure adequate filling ability, passing abilities and segregation resistance.

Self Compacting Concrete

Self-consolidating concrete is a highly flowable type of concrete that spreads into the form without the need for mechanical vibration. Self-compacting concrete is a non-segregating concrete that is placed by means of its own weight. The importance of self-compacting concrete is that maintains all concrete's durability and characteristics, meeting expected performance requirements.

Self-Compacting Concrete Properties

Self-compacting concrete produces resistance to segregation by using mineral fillers or fines and using special admixtures. Self-consolidating concrete is required to flow and fill special forms under its own weight, it shall be flowable enough to pass through highly reinforced areas, and must be able to avoid aggregate segregation.

Self-Compacting Concrete Special Considerations

Self-compacting concrete can have benefits and will shorten your construction time. However, special attention should be focused on:

- A full capacity mixer of self-compacting concrete might not be feasible due to potential spillage along the road, producing environmental and contamination hazards.
- Formwork should be designed to withstand the fluid concrete pressure that will be higher than regular concrete. Self-Consolidating Concrete may have to be placed in lifts in taller elements.
- Production of SCC requires more experience and care than the conventional vibrated concrete.

Mechanism for achieving self-compactability

The method for achieving self-compactability involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when the concrete flows through the confined zone of reinforcing bars. Okamura and Ozawa have employed the following methods to achieve self- compactability.

Benefits & Advantages of Self Compacting Concrete

Self compacting concrete (SCC) can be classified as an advanced construction material. The SCC as the name suggests, does not require to be vibrated to achieve full compaction. This offers following benefits and advantages over conventional concrete.

- Improved quality of concrete and reduction of onsite repairs.
- Faster construction times.
- Lower overall costs.
- Facilitation of introduction of automation into concrete construction.
- Improvement of health and safety is also achieved through elimination of handling of vibrators.

Fiber Reinforced Self Compacting Concrete

"Fibre reinforced self-compacted concrete"(FRSCC) can be produced from cement, different sizes of aggregates, which incorporate with fibres. Fibre reinforced concrete can be explained as concrete having dispersed randomly oriented fibres. Generally concrete is brittle under tensile loading but mechanical properties of concrete may be improved by randomly oriented discrete fibres which prevent as well as control origination, propagation or merging of cracks.

Fibre Reinforced Concrete

Concrete containing cement, water, aggregate, and discontinuous, uniformly dispersed or discrete fibre is called fibre reinforced concrete. It is a composite obtained by adding a single type or a mix together of fibres to the conventional concrete mix. Fibres can be in form of steel fibres, glass fibres, natural fibres, synthetic fibres, etc. Optimization of mechanical and conductivity properties can be achieved by combining different kinds, types, and sizes of fibres, such as in case of Polypropylene fibre (PP) and Steel fibre (S) the attractive advantages of hybrid fibre systems: Hybrid Fiber

Reinforced Concrete (HFRC) is produced from a combination of different types of fibres, which vary in material properties, remain bonded jointly when added in concrete and preserve their identities and properties.

Types Of Fibre

The concrete element technologists have been concentrated on the investigating the mechanical and durability properties of fibre reinforced concrete (FRC) incorporating various types of fibres are given below.

- Glass fibres
- Steel fibres
- Polypropylene fibres
- Nylon fibres
- Carbon fibres
- Basalt fibres
- Asbestos fibres, etc.

Steel Fibre

This is used to the concrete and the ductility performance of the concrete, in the development of its stress-strain relationship behaviour. Additionally, it proves that, the steel-fiber concrete preserved it is good ductility performance, even when exposed to substantially high temperatures.

Polypropylene Fibre

It is a polymer of polyolefin. This shows high alkaline resistive and acid resistive property. Polypropylene fiber in the form of fibrillated film fibers show excellent bonding with matrix, thus giving excellent impact resistance. It could be used where high energy absorption is required for the reason that their high elongation (15-25%) in absorbing more energy.

Beam

The use of fibre reinforced concrete beam has a good reputation and it has turned out be necessary due to the space required in modern construction Industry. Into construction, beams are generally used in water tanks, underground bunkers, silos, nuclear reactors, pile cap etc. Intermittently walls also act as vertical beams and designed as fibre reinforced concrete beams.

Methodology

The experimental studies are prepared on various parameters like flow properties, compressive, splitting tensile, flexural strength, and durability properties by means of different mix ratio of fibres. And this chapter furthermore explains about the mix design, preparation of test specimens employed in the work. The present work as well includes serviceability of beam in terms of deflections, energy absorptions, stiffness and toughness. The explanation of each of the material and methods of testing are illustrated in the following parts.

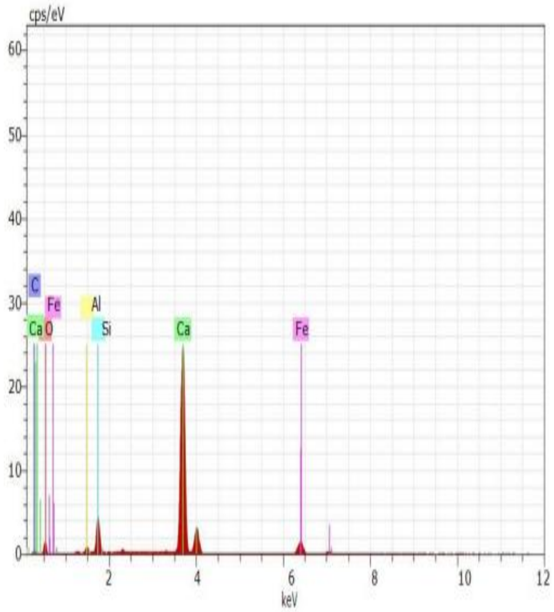
Cement

The Ordinary Portland cement of 53 grade (similar to ASTM Type I) (Ultra tech – Brand) was used for this research. And tests were conducted to establish different properties in accordance with IS: 4031–1988 and they were found to conform to IS: 12269–1987. The physical and chemical properties of the cement are given in below Table. The energy dispersive X-Ray scan images of cement as shown in below Figure. The elements and their percentage of weights present in the cement are given in below Table.

Table: EDX for cement

S.No	Element	Weight (%)	Atom (%)
1	Oxygen ,O	33.43	50.45
2	Calcium, Ca	46.86	28.24
3	Carbon ,C	6.07	12.23
4	Silicon ,Si	6.24	5.37
5	Iron ,Fe	6.27	2.72

3	Aluminum, Al	6.27	1.03



Graph: Energy dispersive X-ray scan images of cement

Polypropylene Fibre

It is a synthetic carbon polymer, is produced as ongoing mono – filaments, mutually circular cross section that can be chopped to required length (or) tape of rectangular cross section. It is manufactured from Radhakrishna Chemical malad west associate, Mumbai and it is obtained from Moon opticals, Madurai. Polypropylene fibres are severe anyhow by all of low tensile strength and modulus of elasticity. Furthermore, their ability to cause interference with the capillary forces how water bleeds to the surface of concrete reduces the risk of plastic settlement due to water evaporation. Polypropylene is may be economical, and can be made translucent when uncoloured but is not as well made transparent as polystyrene, acrylic or certain other plastics. It is regularly opaque or coloured by pigments. Polypropylene has good resistance to fatigue. Perfectly isotactic polypropylene has a melting point of 171o C meanwhile commercial isotactic polypropylene has a melting point ranging from 160o C to 166o C.

Figure: Polypropylene fibre

The 12 mm length polypropylene fibre is shown in aboveFigure. It prevents the micro shrinkage cracks developed during hydration, making the structure component inherently stronger. The bulk density (without compaction) of polypropylene is 175 kg/m3. Below table gives properties of fibres.

Table: Properties of polypropylene fibre

Properties	**Poly-Propylene Fibre**
Length (mm)	12
Density (kg/m3)	176
Aspect ratio	317
Modulus of elasticity (GPa)	3.5
Tensile strength (MPa)	400
Elongation at break (%)	> 100

Steel Fibre

The steel fibres are classified into following types: Straight, Hooked, Paddled, Deformed, Crimped, and Irregular. In this work field crimped types of steel fiber used is shown in below Figure. The design of steel fibres commonly includes carbon steel or stainless steel. The length dimension ranges from 6.4 mm to 76 mm at the same time the diameter ranges from 0.25 mm to 0.75 mm. The steel fibres are described by a convenient parameter "Aspect Ratio". The aspect ratio is determined by length to diameter ratio. It varies from 20 to 100. According to ASTM A 820 standards, the minimum yield strength of steel fibres should be 50,000 psi (345 Mpa). The steel fibre used in this project is crimped type steel fibre and it has 30 mm length and less than 0.5 mm thickness in various percentage of total volume of concrete.

Figure: Steel fibre

RESULTS AND DISCUSSION

Compaction factor test results

The compaction factor test values of different mix proposition of fibers are given in below table. Control specimens were marked as CC. Steel fibre specimens were marked as S; Polypropylene specimens were marked as P; and mix of steel with polypropylene, named as hybrid, were marked as H.

Table: Compaction factor test

S. No	Notation	Percentage of Fibres Added		Compaction Factor
		Steel fibres by volume of concrete (%)	Polypropylene fibres by volume of concrete (%)	
1	CC	0	0	0.9
2	S1	0.25	0	0.89
3	S2	0.5	0	0.88
4	S3	0.75	0	0.85
5	S4	1	0	0.82
6	P1	0	0.25	0.89
7	P2	0	0.5	0.87
8	P3	0	0.75	0.85
9	P4	0	1	0.84
10	H1	0.25	0.25	0.87
11	H2	0.25	0.5	0.86
12	H3	0.5	0.25	0.85
13	H4	0.5	0.5	0.81
14	H5	0.75	0.25	0.80
15	H6	0.25	0.75	0.80

Slump test results

The slump test values of different mix proposition of fibers are given in below table. Control specimens were marked as CC. Steel fiber specimens were marked as S; Polypropylene specimens were marked as P; and mix of steel with polypropylene, named as hybrid, were marked as H.

Table: Slump test

S. No	Notation	Percentage of Fibres Added		Compaction Factor
		Steel fibres by volume of concrete (%)	Polypropylene fibres by volume of concrete (%)	
1	CC	0	0	2.1
2	S1	0.25	0	1.9
3	S2	0.5	0	1.8
4	S3	0.75	0	1.2

5	S4	1	0	1.0
6	P1	0	0.25	1.8
7	P2	0	0.5	1.6
8	P3	0	0.75	1.2
9	P4	0	1	1.1
10	H1	0.25	0.25	1.75
11	H2	0.25	0.5	1.35
12	H3	0.5	0.25	1.45
13	H4	0.5	0.5	1.0
14	H5	0.75	0.25	1.2
15	H6	0.25	0.75	1.1

Structural Behaviour Of Beams

The investigation results for beam specimens had been cast and had been tested for structural behaviour at the age of 28 days. The initial load, ultimate load and ultimate deflections of beams have been presented in Table 4.13. All the beams that had been taken into considering in this investigation had been tested up to their collapse. The beams were subjected to an augmentation of point loads. The first crack load is found for all the beams. In the structural behaviour of the beams is studied with measurement of deflection and crack pattern.

Finite Element Validation Of Experimental Results

Finite Element Method (FEM) has been proved to be a suitable method to study the nonlinear behaviour of the reinforced concrete (RC) structures. The finite element analysis calibration study is based on modelling a concrete beam with the dimensions and properties. The nonlinear model of beam has been formed in ANSYS with appropriate numerical modeling. These methods were suggested and their relationships with load deflection were also discussed.

Table: Input data for material properties of concrete

Mix Proportion	fc' (N/mm^2)	E (N/mm^2)	f_r	υ	β
CC	32.44	3×10^4	4.65	0.26	0.2
SC4	35.42	3.93×10^4	6.5	0.24	0.2
PPC4	35.38	3.41×10^4	5.9	0.24	0.2
HYC5	45.64	4.73×10^4	7.7	0.24	0.2

Table: ANSYS coordinates of beam

ANSYS coordinates	Dimensions (mm)
X- coordinate	1200
Y-coordinate	150
Z-coordinate	150

Displacement boundary conditions had been necessary for the constraint of the model to obtain a unique solution. To ensure the same experimental beam boundary conditions requirement and this method is to be applied at points of symmetry, and where the supports and loading exist. And finally, the support was modelled as a simply support at both ends.

Meshing of the entirety structure is another step in ANSYS that is used to define the type of element and the structure to be sub divided into smaller elements. To acquire good results from the Solid65 element, the utilization of a rectangular mesh was suggested. And hence, the meshing of the reinforcement was treated a special case to be compared to the volumes. Thus, the mesh was set up in a unique way that square or rectangular elements were created. The meshing of the reinforcement had been a special case contrasted to the volumes. The separated structure boundary conditions and loads are specified. Particularly, the loads have been given on the respective nodes and support conditions on main points.

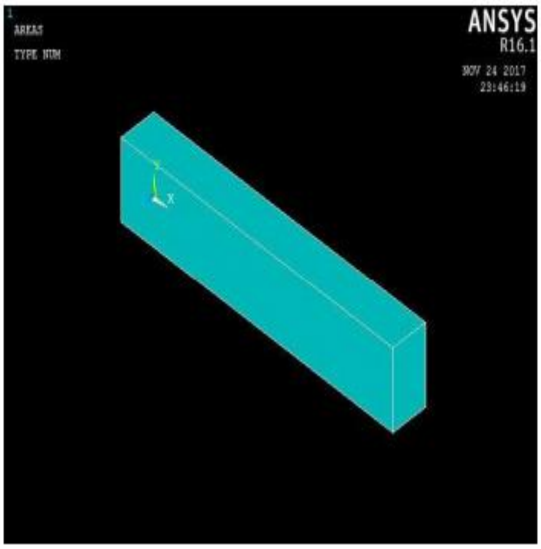


Figure: Modelling of beam

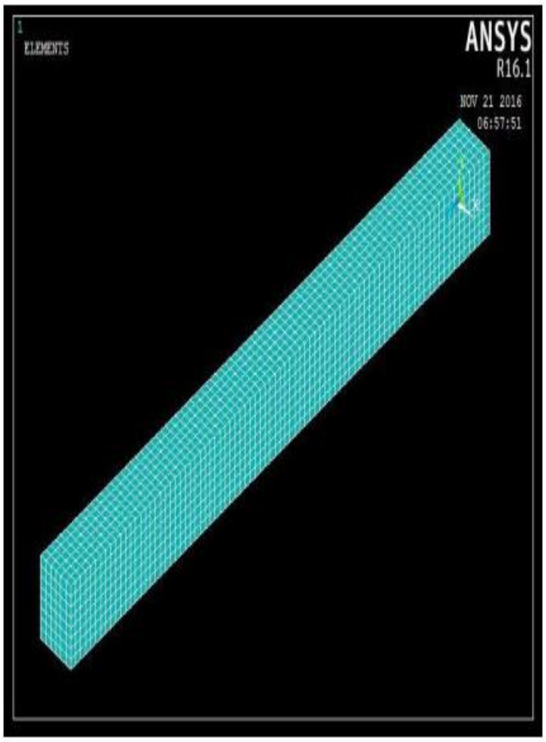


Figure: Meshing of beam

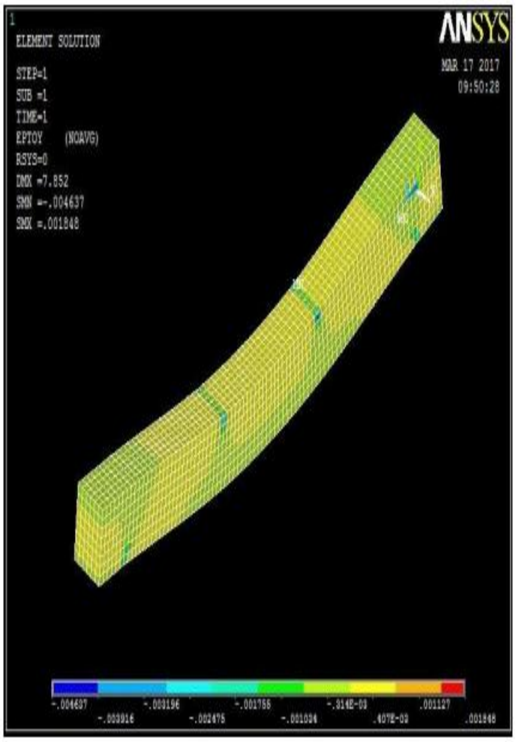


Figure: Deflection of beam

Conclusion

In this study presents the conclusion is based on the experiments carried out intensively. Besides, the study is intended to the scope for future research. The effect of including fibre, hybrid fibre in CC for strength and durability characteristics explores the unfavourable environment. The results have also been compared with Finite Element Analysis (FEM) by using ANSYS software.

In view of the above discussions we can conclude as under :-

Glass fibre reduces the possibility of cracks and improves the surface integrity as well as its homogeneity by the reduction in bleeding.

Workability of self compacting concrete decreases with increase in steel fibre volume fraction. However, higher workability can be achieved with the addition of high range water reducers.

Glass fibres increases the strength of concrete, without causing any problems.

The addition of steel and glass fibres increases the compressive strength to a great extent.

The addition of steel and glass fibres improves the durability and the fracture parameters of concrete.

Future scope

The present investigations were carried out to study the behaviour of hollow beams with self compacting concrete and reinforced with hybrid fibers. There is scope for continuing studies in this area as mentioned below.

- This research work has covered only the beams and it can be extended to columns and slabs with openings.
- The torsion behaviour of hollow beams can be investigated.

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