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Reinforced Concrete Beam with Light Weight blocks and Steel Fibre added below Neutral Axis

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Abstract: ***The reinforced concrete is one of the widely used structural materials which have its own major advantages and disadvantages. Its behaviour when provided in various positions in the structural elements like compression, tension, and shear zones has significant impact. Since the concrete is excellent in the compression behaviour, and only a nominal performer in the tension behaviour, steel reinforcement are provided in required zones where tension occurs. Thus in a bending member, below the neutral axis, that is at the tension zone, the concrete acts only as a interface medium between reinforcement that carrying the tension and the concrete above neutral axis carrying compression forces. This concrete is also called as sacrificial concrete. Thus in order to efficiently use the concrete falls under the tension zone, the concrete can be swapped with any suitable lighter or cheaper material or the concrete may be strengthened to carry tensile stresses. In this present study, the concrete below neutral axis is replaced with lightweight 'aerocon' block cubes of 8 cu.cm and 64 cu.cm by 20% of volume of concrete and in another specimen, steel fibres are added in the concrete that are below neutral axis by 2% and 3% by weight to improve the local tensile strength of concrete as material The results obtained shows that the aerocon cubes replaced specimens has equivalent performance of the control specimen and the steel fibre added specimen had superior deflection and crack performance than the control specimen.***

Keywords **:** ***Sacrificial concrete, Aerocon blocks, Hooked steel fibre, neutral axis.***

I. INTRODUCTION

The concept of optimizing of resources for reinforced concrete is now-a-days the leading research area in structural engineering. The flexural strength of a component is important for designing the dimensions and materials to be used for the construction of the beams. The sacrificial concrete below neutral axis is not efficient in resisting the tensile stress. It is found through researches, there are innumerable methods for improving the efficiency of concrete at the tension zone such as prestressing, selection of Tee-beam cross section and enlargement of section.

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Other alternate method of increasing the efficiency of concrete below neutral axis without affecting the shape or geometry is studied in this context of work. One of the method deals with imparting steel fibres in the concrete below neutral axis since the hooked steel fibres are known for its tensile strength. Another method deals with the replacement of sacrificial concrete with light weight cubes otherwise called as aerocon blocks. In this investigation beam specimen with steel fibres and aerocon blocks are tested individually to find its improvement in flexural strength.

Aylie et al conducted experimental tests on specimen of reinforced concrete beams added with steel-fiber with confinement where the efficacy of combination of concrete with steel-fibre and confinement of the concrete in the compressive zone of the beam element were studied. It was concluded that it influences the moment at the cracking point and the ultimate moment capacity positively. Soman et al concluded that the concrete in the tension zone acts as strain transferring medium (also termed as sacrificial concrete) could be partially substituted by light-weight air voided materials. It was concluded that the ultimate strength capacity is not much affected and the self-weight is significantly reduced. Mathew et al used waste plastic bottles for partial replacement below neutral axis to bring down the self-weight of the concrete without much distressing the bending strength. Kumar et al concluded that the initial cracking load and the peak load carrying capacity were increased while strengthening the concrete at the tension zone by introducing air voids.

In the present context, two concepts were undertaken to equate the flexural strength of the flexural element and the effectiveness of concrete in tension zone. The behavior of the beam, when added with steel fibres (hooked) provides tensile strength to the sacrificial concrete, is studied. The steel fibres are provided in the concrete to increase the strength of the concrete in tension such that it will resist the tension and hence to increase the ultimate strength capacity. Also the effectiveness of the sacrificial concrete when partially replaced with aerocon blocks is studied. Here the self-weight of flexural element is reduced by replacing the sacrificial concrete without significantly affecting the strength capacity of the beam in flexure.

II. SCOPE AND OBJECTIVE

From the literature studies it is known that the concrete in tension zone is strengthened by adding materials like bricks, polythene balls etc.

The intention of this work is to increase the ultimate moment resisting capacity and initial cracking load, by adding steel fibres in tension zone and replacing the concrete by aerocon blocks and to study the variation in efficiency of these different beam specimens when compared with the control beams. The replacement of concrete in the tension zone (ie. below neutral axis) with aerocon blocks is to make it more efficient and sustainable by reducing the self-weight, saving the amount of concrete used and cost. Whereas, the steel fibres added in the tension zone are expected to increase the tensile strength of concrete particles.

III. SPECIEMEN DETAILS

A total of five beams were casted. One reinforced concrete beam with ordinary concrete material serves as a control beam. Two beam specimens with steel fibres of 2% and 3% by weight of cement added below neutral axis. Another two beam specimens in which 20% volume of concrete is replaced with aerocon block cubes of $8cm^3$ and $64\ cm^3$ respectively. The Table I describes the specimen designation used in the study.

Table I. Specimen details

SL. No	Material adopted	Percentage fraction added/replaced	Specimen Designation
1	Ordinary concrete	-	CB
2	Hooked steel fibres	Added 2% by weight of cement	SF2
3	Hooked steel fibres	Added 3% by weight of cement	SF3
4	Aerocon blocks	Replaced 20% by volume with $8mm^3$ cubes	AB1
5	Aerocon blocks	Replaced 20% by volume with $64mm^3$ cubes	AB2

All the five beam specimens are provided with a dimension of 250mm x 300mm with an effective span of 2500mm. 3 numbers of 16mm diameter bars at the tension face and 2 numbers of 10mm bars are provided at the compression face such that the beam is designed as singly reinforced beam. The reinforcements used are Fe500 grade steel. Stirrups are provided with 8mm diameter bars at 300mm spacing. The neutral axis depth is calculated as 131mm from the bottom as per code IS456:2000. Fig. 1 shows the reinforcement details if the beam specimens.

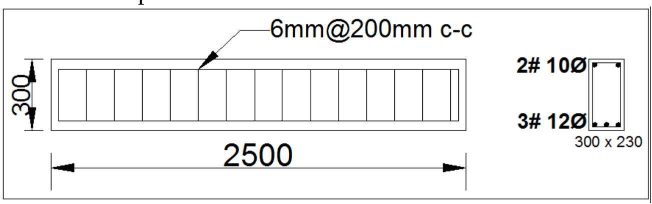


Fig. 1 Reinforcement details

Fig.2 shows the reinforcement cage of the beam provided with the reinforcement mentioned above. Fig. 3 previews the concreting of beam with added steel fibre. Fig. 4 shows the beam mould concreted with aerocon blocks below the neutral axis.

Fig.2 Reinforcement cage of beam

Fig.3 Beam concreted with steel fibre

Fig. 4 Specimen with aerocon blocks

IV. TEST SETUP

In the experimental setup, the beams are simply supported at the ends and the loading is applied from the top of the beam at the one-third of the span. The effective span of the beam is 2500 mm, overall depth is 300mm and the width is 230mm. The investigation on the specimen to perceive the flexural strength of the member casted was conducted using 40T hydraulic jack and reaction loading frame. The deflection was observed at various points of the member using a linear variable differential transducer (LVDT). Fig. 5 shows the test setup followed in the experimental programme. The observations are done once the loading is applied till the failure occurs and the loading is paused once when the specimen reaches the point of collapse. The readings are perceived as the loading increases progressively and defection is noted at various stages during the gradual loading. The load versus deflection curve is plotted from the data obtained.

Fig. 5 Specimen Test Setup

V. EXPERIMENTAL RESULTS

A. Strength Capacity

The load in the beam was given at an incremental interval of 5 kN and the corresponding deflection was recorded. The ultimate load capacity of the beam specimens under two point test was spotted at the point above which the load value shown in the LVDT started reducing even when the hydraulic loading jack was given incremental load. The cracking loads are the loads corresponding to the development of the first crack at the soffit of the beam due to flexure. The trajectory of load-displacement of the entire specimen is shown in the following graphs. The specimen CB, SF1, SF2, AB1, AB2 recorded an ultimate load of 91.1 kN, 99.9 kN, 97.0 kN, 95.2 kN and 94.4 kN respectively. Thus there is 9.65% increase and 6.47% increase in beam specimen SF1 and SF2 respectively compared to strength capacity of specimen CB. Also there is 4.39% and 3.18% increase in beam specimen AB1 and AB2 respectively compared to the strength capacity of CB. The strength capacity is increased in beam with steel fibres whereas it is not much affected in that of beam specimen with aerocon blocks. Table II and Fig. 6 shows the strength capacity of the specimen in flexure. Also the maximum displacement of the specimens are discussed in the Fig. 7.

Table II. Strength capacity of specimens

Sl. No.	Specimen	Ultimate Load Capacity (kN)
1	CB	91.1
2	SF1	99.9
3	SF2	97.0
4	AB1	95.2
5	AB2	94.4

B. Deflection Behaviour

The deflection of the beam at the mid span is considered and is plotted in graph against the applied load. Consequently the flexural strength of the specimen is studied using the graph. The trajectory of load- deflection of the entire specimen is shown in the following graphs. The plot represents the stiffness of the beam by the deflection behavior with respect to corresponding load values. It was observed that the addition of steel fibre and the aerocon block in the neutral axis improved the stiffness of the beam. Fig. 8 shows the load deflection behaviour of the test specimens when subjected to flexural loading.

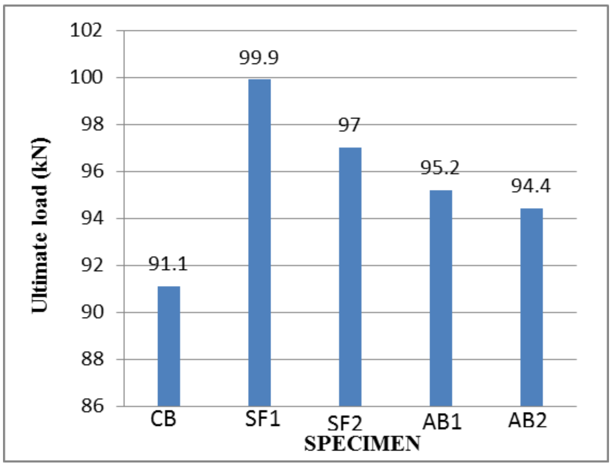


Fig.6 Comparison of strength capacity of specimens

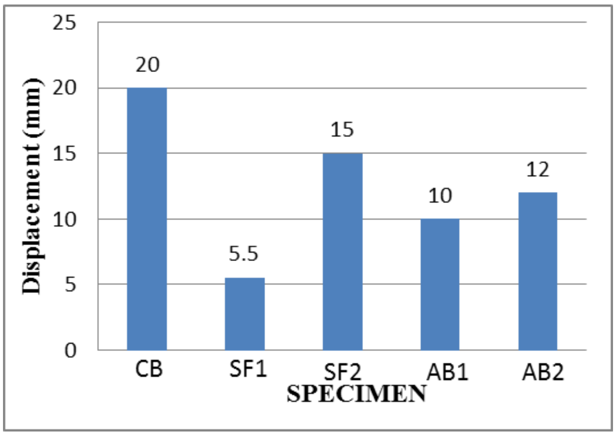
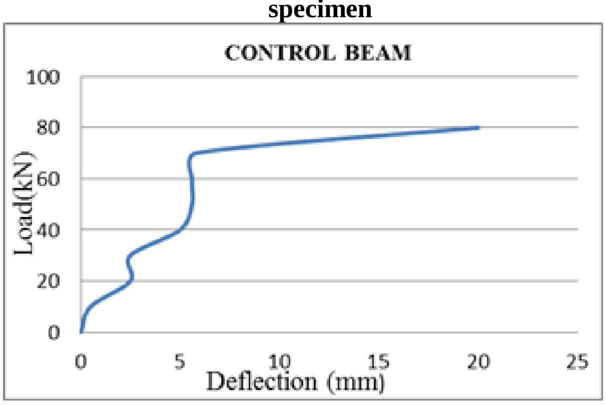
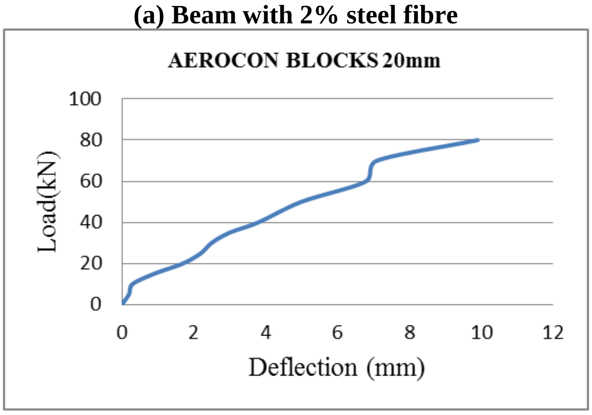


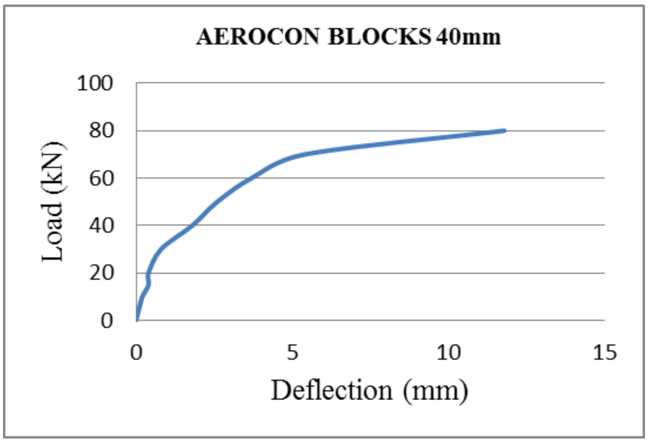
Fig.7 Comparison of maximum displacement of beam specimen



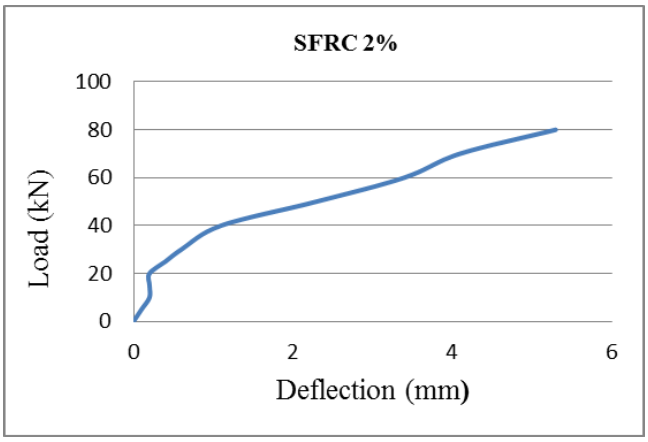
(a) Beam with 2% steel fibre



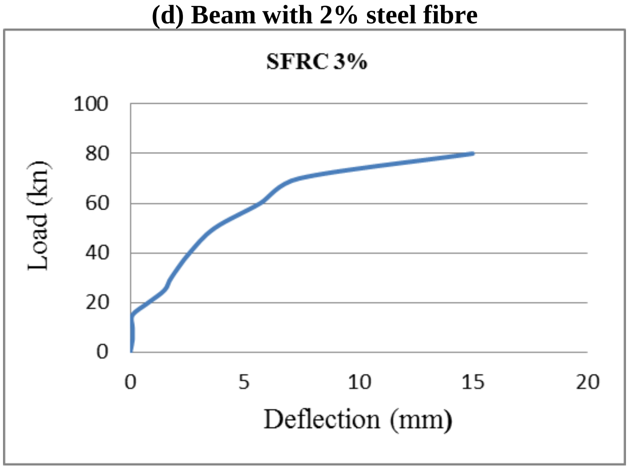
(b) beam with 20mm aerocon blocks



(c) Beam with 40mm aerocon blocks



(d) Beam with 2% steel fibre

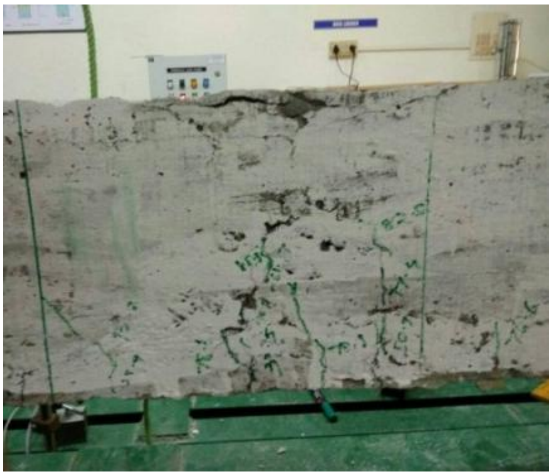


(e) Beam with 3%steel fibre

Fig. 8 Load-Deflection behaviour

C. Crack Pattern

As the loading progressed, cracks pattern were closely observed at each load increment. Cracks were developed which are found to be more near the supporting ends due to shear and minimal in the mid span. When the beam specimen reaches the ultimate load cracks due to crushing are found in the mid span at the compression zone. The first crack loads and the crack pattern formed during ultimate load are observed carefully. Fig, 9 shows the crack pattern if the specimens when subjected to flexural loading.



(a)

(b)

Fig. 9 Crack pattern in beam specimens

VI. CONCLUSION

In the current study, flexural tests were conducted on the beams with concrete replaced with lightweight block below the neutral axis / in the tension zone and provided with steel fibre at the tension zone, and the following conclusion are drawn

- The replacement of concrete by aerocon blocks in low stressed zone which is to reduce the self-weight has not resulted in any significant depletion in the strength of concrete.
- Increase in ductility and ultimate flexural strength in the specimen beam is been influenced by the quantity of steel fibres used.
- The most important contribution of steel fibre reinforcement in concrete below neutral axis is not only to elevate the strength but also to increase the flexural toughness of the material.
- Control beam failed suddenly once when the deflection correlating to the ultimate flexural strength is crossed, whereas beam specimen with aerocon blocks and steel fibres are found to continue to withstand the loads even at deflections in surplus of that failure deflection of control beam.

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AUTHORS PROFILE

Dr.P.S.Aravind Raj, has completed his doctorate in structural engineering in the year 2015 and has a total research experience of about 8 years. He is passionate on research in the fields of steel-concrete composites, sustainable materials, sustainable structures, etc. He has performed several research on beam-column connection of composite structures. He published and presented his research in many National as well as International conferences and also peer reviewed journals. Currently he is working as Associate Professor in the Department of Civil Engineering, Aarupadai Veedu Institute of Technology, Paiyanoor, Chennai from May 2019.

F.S.Frieda, has completed her Masters in structural engineering in 2015, she has a passion towards teaching with 4 years of experience and has an extensive interest in the field of research and has done various researches with various steel beam column connections, permeable concrete and has discerned various sustainable solutions using Internet of things in the field of civil engineering, she is an active member of various professional societies like Indian concrete institute and The institution of Engineering and Technology. She has published and presented in various national and international conferences. She has also been recognised and awarded as the "Best teaching faculty" and received the "Best project award" from IET in the year 2018 & 2019. Currently working as Assistant Professor, Department of Civil Engineering, KCG College of technology, Chennai.

Dr.S.P.Sangeetha, Vice Principal Academics, Professor, Department of Civil Engineering is a Civil Engineer completed her Masters and Doctoral degree in Structural Engineering. Has wide experience in Teaching and Designing. She is a active member in Professional societies like American Concrete Institute, ISTE,IAENG,Chennai Civil Engineers ATCECEA,ACCE,ISTE,ACE,etc..She has delivered Technical lectures in various Institutions. She is the Programme Director for Institutional Social Responsibility cell to Inculcate Social awareness, values and environmentally responsible behaviour amongst students.She has received “Best faculty award “from DKRF and “Best recognition award “from Rotaract club of Chennai..

Dr.R.Divahar was awarded a Ph.D in Civil Engineering (Structural Engineering Specialization) from Hindustan University, India at 2015 and authored a research thesis titled “Behaviour of Cold-Formed Steel Beam with Concrete Encased Trapezoidally Corrugated web. Presently He have more than 9 years of teaching and industrial experience. His inventions are patented and published in India at Jan 2018. He published and presented his research in many National as well as International conferences and also peer reviewed journals. He published more than 25 papers, maximum peer reviewed journal papers was indexed by Scopus, Elsevier, Springer & Science Citation Indexed. Currently he is working as Associate Professor in the Department of Civil Engineering, Aarupadai Veedu Institute of Technology, Paiyanoor, Chennai from May 2019 onwards. His current area of research is Cold-Formed Steel Structure, Concrete and Composite Structure and Finite Element Analysis