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Behaviour of Deep Beams with Circular Openings Using Waste Materials as Fiber Reinforcement

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Abstract

This paper presents the details of behavior of RCC beams with circular openings under point load using fibers from different waste materials like steel filings, mild steel lathe waste and fibers from beverage tins. In this program of 12 cubes, 12 prisms and 12 cylinders were cast and tested for establishing the compressive strength, flexural strength and split tensile strength of four concrete mixes used in the investigation. Also a total number of 10 deep beams of size 900mmx200mmx500mm (L x B x D) were cast out of which 4 specimen were of conventional concrete and remaining 6 specimens were fibre reinforced concrete with opening size of dia. 115mm. The deep beams were tested under central point loading for determining strength and cracking characteristics. It was found that all the 3 types of fibre reinforced concrete exhibited and enhanced compressive, flexural and split tensile strength properties when compared to that of conventional concrete. The deep beams with openings constructed with fibre reinforced concrete showed better performance characteristics with respect to collapse and serviceability when compared with that of control specimens, out of 3 types of fibre reinforced specimen the one with small length steel filings as fibre reinforcement exhibited optimum performance.

Keywords

Deep beams, circular openings, steel filing, lathe waste and beverage tins.

I. Introduction

Beams with large depths in relation to spans are called deep beams. As per the Indian Standard, IS 456:2000[1], a simply-supported beam is classified as deep when the ratio of its effective span L to overall depth D is less than 2. The effective span is defined as the centre-to-centre distance between the supports or 1.15 times the clear span whichever is less.[2]

In the construction of modern buildings, many pipes and ducts are necessary to accommodate essential services like water supply, sewage, air-conditioning, electricity, telephone, and computer network. Usually, these pipes and ducts are placed underneath the beam soffit and, for aesthetic reasons, are covered by a suspended ceiling, thus creating a dead space. Passing these ducts through transverse openings in the floor beams leads to a reduction in the dead space and results in a more compact design. For small buildings, the savings thus achieved may not be significant, but for multi-storey buildings, any saving in story height multiplied by the number of stories can represent a substantial saving in total height, length of air-conditioning and electrical ducts, plumbing risers, walls and partition surfaces, and overall load on the foundation.

We knew that inclusion of openings in beams alters the simple beam behaviour to a more complex one. Due to abrupt changes in the sectional configuration, opening corners are subject to high stress concentration that may lead to cracking unacceptable from aesthetic and durability viewpoints. The reduced stiffness of the beam may also give rise to excessive deflection under service load and result in a considerable redistribution of internal forces and moments in a continuous beam. Unless special reinforcement is provided in sufficient quantity with proper detailing, the strength and serviceability of such a beam may be seriously affected.

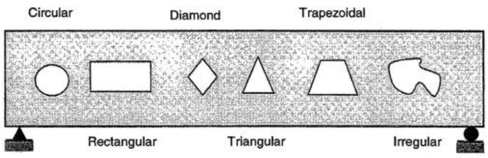

Fig. 1: Different types of openings the beam

Transverse openings in beams may be of different shapes and sizes such as openings of circular, rectangular, diamond, triangular, trapezoidal and even irregular shapes openings of circular, rectangular, diamond, triangular, trapezoidal and even irregular shapes as shown in figure 1. Sometimes the corners of a rectangular opening are rounded off with the intention of reducing possible stress concentration at sharp corners, thereby improving the cracking behaviour of the beam in service. With regard to the size of openings, many researchers use the terms small and large without any definition or clear-cut demarcation line. Mansur and Hasnat have defined openings circular, square, or nearly square in shape as small openings. According to Somes and Corley, a circular opening may be considered as large when its diameter exceeds 0.25 times the depth of the beam web.

Great quantities of steel waste fibers are generated from industries related to lathes, empty beverage metal cans. This is an environmental issue as steel waste fibres are difficult to biodegrade and involves processes either to recycle or reuse. The metallic wastes obtained from various sources such as mild steel lathe waste, empty beverage tins are deformed into the rectangular form with an approximate size of 3mm wide and 10mm long as in the form of fibres. These fibres are added in the concrete with 1% by weight of concrete [4].

The main factors affecting the behavior and performance of deep beams with web openings are:

i. Span to depth ratio of beam.

ii. Cross-sectional properties (i.e. circular section, Tee-section, etc.).

iii. Amount and location of main longitudinal reinforcement.

iv. Amount, type and location of web reinforcement.

v. Properties of concrete and reinforcements.

vi. Shear span to depth ratio.

vii. Type and position of loading.

viii. Size, shape and location of web opening etc.

The objective of this investigation was to study the behaviour of RCC beams with circular openings under point load using fibers from different waste materials in general and also to determine compressive strength, flexural strength and split tensile strength of concrete with waste materials as fibre reinforcement. The waste materials to be used for casting are beverage tins, steel filings and mild steel lathe waste in particular and to study the Load deflection behaviour and crack pattern.

II. Experimental Programme

A. Materials

Cement, Fine aggregates, Coarse aggregates, Water, Beverage tins, Fibrous lathe waste and Lathe waste small length steel filings were used in the investigation.

1. Cement: Ordinary Portland Cement 53 Grade (OPC) (Ultratech Cement). It was tested for its properties in accordance with Indian Standard specifications[1] and the test results are shown in table 1.

Table 1 Properties of Cement

Sl.No.	Preliminary Tests	Results
1	Normal Consistency	28%
2	Initial Setting Time	30 mins
3	Final Setting Time	8 hrs
4	Specific Gravity	2.8
5	Soundness	1 mm

2. Fine Aggregates: Natural river sand with maximum particle size of 4.75mm confirming to IS 383-1970[5] was used for present work. The properties of the fine aggregates determined in the laboratory are listed in table 2.

Table 2 Properties of Fine Aggregate

Sl. No.	Preliminary Test	Results
1	Grading Zone	Zone II
2	Specific Gravity	2.66
3	Water Absorption	1.2%
4	Moisture Content	0 %

3. Coarse Aggregate: Crushed stone aggregates of maximum nominal size of 20mm confirming to IS 383-1970 [5] was used. The properties of the coarse aggregates are presented in the table 3.

Table 3: Properties of Coarse Aggregate

Sl. No.	Preliminary Test	Results
1	Bulk Specific Gravity	2.73
2	Specific Gravity	2.72
3	Water Absorption	0.76 %
4	Moisture Content	0.2 %

4. Water: Potable water confirming to IS 456-2000[1] was used for both casting and curing.

5. Beverage Tins: The waste beverage tins were used as fiber reinforcement, which were cut into size of 3mmx10mm, keeping an aspect ratio of 3. The basic properties of beverage tins from the source are listed in table 4. The properties of fibers obtain from the beverage tin and fibres obtained are shown in plate 1.

Table 4: Properties of Beverage Tins

Sl. No	Basic Properties	Value
1.	Density	2.75 gm/cc
2.	Young's Modulus	70 GPa
3.	Aspect Ratio	3

Plate 1: Beverage Tins as Fiber reinforcement.

6. Mild Steel Lathe Waste: The waste steel obtained from lathe was used as Fiber Reinforcement, the size of the mild steel lathe waste used as Fiber reinforcement is cut into 5mmx12.5 mm. The aspect ratio was 2.5. The basic properties of mild steel lathe waste from the source are in table 5 and fibres obtained are shown in plate 2.

Table 5 Properties of mild Steel Lathe Waste

Sl. No	Basic Properties	Value
1	Density	7.8 gm/cc
2	Young's Modulus	210 GPa
3	Aspect Ratio	2.5

Plate 2 Mild Steel Lathe Waste

7. Small Length Steel Filings: The small length steel filings are obtained from the lathe is sieved in 2.36mm sieve and the material passing is used as Fiber reinforcement. Average size of the powder is 0.5x 1.8mm. The aspect ratio is 3.6. The properties are listed in table 6 the steel filings used in this investigation are shown in plate 3.

Table 6 Properties of small length steel filings

Sl. No	Basic Properties	Value
1	Density	7.85 gm/cc
2	Young's Modulus	210 GPa
3	Aspect Ratio	3.6

Plate 3 Small Length Steel Files

B. *Concrete mix proportion:*

Mix design procedure was carried out as per IS 10262-2009 taking grade of concrete as M20. The mix proportion obtained was 0.5:1:1.5:3.1 (water: cement: fine aggregate: coarse aggregate). For all beams fiber reinforcement, the weight fraction of the fiber was maintained at 1 %.

C. *Specimen Details*

1. Cube Specimen

To determine the compressive strength cubes of size 150mx150mmx150mm were used. The total number of 12 cubes specimen were cast out of which three cubes were made up of control concrete (S1), three cubes with small length steel filings as fibers (S2), three cubes were with beverage tins as fibers (S3) and three cubes with regular mild steel lathe waste as fiber reinforcement (S4). All the cube specimens were demoulded after 24 hours from casting and kept in the water tank for 28 days curing. Testing of cube specimens is shown in Plate 4.

2. Prism Specimens

Prism specimens of size 150mx150mmx150mm were cast for determining static flexural strength. The total number of 12 prism specimens were cast out of which three prisms were made up of control concrete (S1), three prisms with small length steel filings as fibers (S2), three prisms were with Beverage tins as fibers (S3) and three prisms with regular mild steel lathe waste as fiber reinforcement (S4) were used in the investigation. All the prism specimens were demoded after 24 hours from casting and kept in the water tank for 28 days curing. Testing of prism specimens is shown in Plate 5.

3. Cylinder Specimens

To determine the Split tensile strength cylinders of size 150mx300mm were used. The total number of twelve cylinders specimen were cast out of which three cylinders were made up of control concrete (S1), three cylinders with small length steel filings as fibers (S2), three cylinders were with Beverage tins as fibers (S3) and three cylinders with regular mild steel lathe waste as fiber reinforcement (S4). All the cylinder specimens were demoulded after 24 hours from casting and kept in the water tank for 28 days curing. Testing of cylinder specimens is shown in Plate 6.

D. *Tests conducted:*

1. *Cube Compression Test:* Cube specimens are used for determining compressive strength as per IS: 516-1959[6]. The cubes are tested in a compression testing machine of capacity 2000KN. Load is applied in such a way that, the two opposite sides of the cube are compressed (Top and Bottom surface). Arrangement of test setup is shown in plate 4. The load at which the control specimens ultimately failed is noted. Compressive strength is calculated by dividing the load by area of specimen.

$F_c = P_c/A$

Where, F_c = cube compressive strength in N/mm^2
P_c = load applied on cube in N
A = Cross section area of cube

Plate 4 Testing of Cube Specimens

2. *Flexural Test:* Prism specimens are used for determining flexural strength as per IS: 516-1959[6]. Flexural strength of prisms is tested under universal testing machine. The symmetric loading arrangement with load applied at 1/3rd points producing pure bending zone with zero shear within the middle third span. The arrangement of test setup is shown in plate 5. The load is applied up to the ultimate failure. The flexural strength of the prisms is calculated using the equation.

$F_b=(P_b * l)/(b*d^2)$

Where f_b =Flexural strength in N/mm^2

P_b = load causing failure in N

L = Length of prism in mm

b = Width of prism in mm

d = Depth of prism in mm

Plate 5 Testing of Prism Specimens

3. *Split Tensile Strength:* Cylindrical specimens are used for determining split tensile strength as per IS: 5816-1970[3]. Split tensile strength of cylinders is tested under universal testing machine. The cylinder is kept horizontally sandwiched between the iron plates. The load is applied to the ultimate failure. The test setup is shown in plate 6. The split tensile strength of the cylinders is calculated using the equation.

$F_t= 2P/(\pi DL)$

Where, ft = Split tensile strength in N/mm^2

P = Load causing failure in N

D = Diameter of the cylinder in mm

L = Length of the cylinder in mm

Plate 6 Testing of Cylinder Specimen

4. Test specimens

Deep beams of size 200mmx500mmx900mm were used as test specimens. A total number of ten beams were cast. Two beams were of solid sections cast with control concrete (B1 and B2). Another two beams of control concrete (B3 and B4) were cast with circular openings. For beams with steel filings as fiber reinforcement two specimens were cast (B5 and B6), similarly for beams with Beverage tin as fiber reinforcement (B7 and B8) and with mild steel lathe waste (B9 and B10) two beams specimens for each type of mix were used. The diameter of the opening in the beams was kept as 115mm. Reinforcement details: High-Yield Strength Deformed bars of 12 mm and 8 mm diameter are used for the longitudinal reinforcement and 8 mm diameter bars are used as stirrups. The tension reinforcement consists of 2 no's 12 mm diameter HYSD bars. 4 no's 8mm diameter HYSD bars used for side reinforcement. The reinforcement details of the deep beams are shown in plates 7

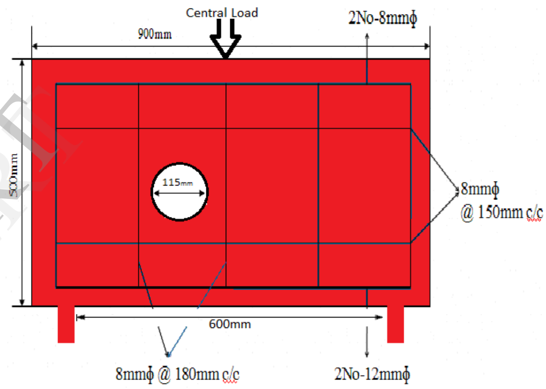

Plate 7: Reinforcement Details of Deep Beams.

After the curing period was over the beams are surface dried. After drying they are cleaned with a sand paper to remove all grit and dirt. Then all the specimens are white washed from all the sides. White wash is done to facilitate easy detection of crack propagation.

The beams are tested under single point load on the loading frame of 1000KN capacity. Beam is kept on point support which was rested on two girders so that we can obtain an effective span 600mm.

On the beam to get required shear span, a cylinder is placed over a beam to get the packing. Hydraulic jack is connected to a pumping unit and is kept over the I-section. Hydraulic jack having the capacity of 500KN was placed on the top face of the beam to facilitate the loading. By using a plump-bob, the centre line of the beam, cylinder and the hydraulic jack were made to coincide with each other in order to prevent eccentric loading on the beam.

With the help of Betty's dial gauge having 0.01mm as least count and 25mm range, the deflections at different loads are measured at the beam centre. When the hydraulic jack is pumped the load is generated over beam due to rising of the jack, the needle indicator from the pump gives the load applied over a beam. Typical test setup is shown in Plate 8.

The beam is kept on the loading frame and all arrangements required are made. The load at first crack and the ultimate point are noted along with a continuous record of load v/s deflection values. The crack patterns for all the beams are also studied.

III. Results and Discussions

In this desertion work, the observations were recorded for cube compressive strength, flexural strength and split tensile strength. Also initial cracking load, ultimate load and cracking characteristics were noted for the test specimen. Average values of two specimens were presented for the test specimens. Average values of three specimens were taken for determining compressive strength, split tensile and flexural strength of concrete respectively.

A. Cube Compressive Strength

The results of 28 days cube compressive strength are tabulated in table 7. for all 4 types of concrete mixes. All the concrete mixes with fibre reinforcement should increase in the compressive strength when compared with that of conventional concrete. The percentage compression strength for the mixes S2, S3 and S4 were found to be 39.1%, 20.4% and 65.1% respectively.

Table 7: Compressive strength of cubes

Sl. No	FRC Specimens with notations	Compressive Strength (N/mm^2)
1	Conventional Concrete (S1)	24.27
2	Steel Powder (S2)	33.75
3	Beverage Tins (S3)	29.21
4	Mild Steel Lathe Waste (S4)	40.08

B. Flexural Strength

The results of 28 days cube flexural strength are tabulated in table 8 for all 4 types of concrete mixes. All the concrete mixes with fibre reinforcement should increase in the flexural strength when compared with that of conventional concrete.

The percentage increase of flexural strength of the specimen S2, S3 and S4 were found to be 6.65%, 31.42%, and 23.86% respectively.

Table 8: Flexural strength of prisms

Sl. No	FRC Specimens with notations	Flexural Strength (N/mm^2)
1.	Conventional Concrete (S1)	3.31
2.	Steel Powder (S2)	3.53
3.	Beverage Tins (S3)	4.35
4.	Mild Steel Lathe Waste (S4)	4.10

C. Split Tensile Strength

The results of 28 days cylinder split tensile strength are tabulated in table 8. for all 4 types of concrete mixes. All the concrete mixes with fibre reinforcement should increase in the split tensile when compared with that of conventional concrete. The specimens S2, S3 and S4 also have a positive effect on the split tensile property. The tensile strength of those specimens was found to be 35.51%, 11.96% and 38.77% greater than that of the conventional concrete.

Table 8: Split tensile strength of cylinders

Sl. No	FRC Specimens with notations	Split Tensile Strength (N/mm^2)
1.	Conventional Concrete (S1)	2.76
2.	Steel Powder (S2)	3.74
3.	Beverage Tins (S3)	3.09
4.	Mild Steel Lathe Waste (S4)	3.83

D. Strength and Serviceability Characteristics of Test Specimens

A typical pattern of load deflection curve for concrete mixes is shown in figure 2. The test setup for the specimens is shown in plates 8. There was a decrease in initial cracking load for all the specimens with openings when compared with that of solid section. The percentage of decrease for conventional concrete, concrete with Steel Filings, concrete with beverage tin fibers and concrete with Mild Steel Lathe Waste fibers were 2.31%, 5.38% and 3.85% respectively.

Plate 8: Loading setup of deep beams

When the results of deep beam with openings were compared among themselves, all the beams with fiber reinforcement showed better performance when compared with conventional concrete beam with opening. The percentages increase in initial cracking load for Steel Filings, concrete with beverage tin fibers and concrete with Mild Steel Lathe Waste fibers were 5.83%, 2.5% and 4.16% respectively. The corresponding percentage increases in ultimate load were 6.88%, 3.75% and 6.25% respectively. The deflection values at initial cracking load were nearly identical.

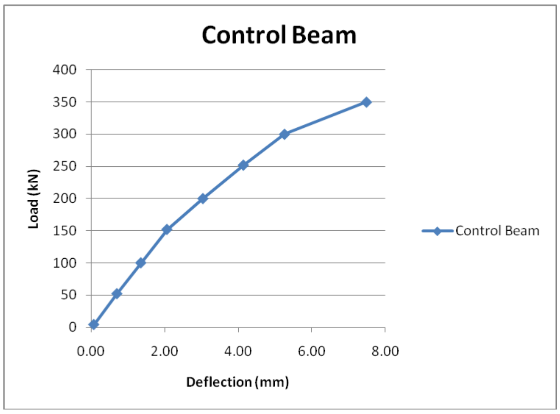

Fig 2: Typical load deflection curve for deep beams

E. Initial Cracking Load and Ultimate Load

Table 9: Average Initial Crack Value and Average ultimate Load

Sl. No	Specimens	Average Initial Cracking load (KN)	Deflection at initial cracking load (mm)	Average Ultimate Load (KN)
1	B1 & B2	260	4.34	350
2	B3 & B4	240	4.15	320
3	B5 & B6	254	4.08	342
4	B7 & B8	246	3.9	332
5	B9 & B10	250	4.0	340

IV. Conclusions:

The following conclusions were drawn from the results of present investigation.

1. When compared with the values of conventional concrete the Compressive strength of concrete reinforced with Steel Filings, concrete with fibres Beverage tin and concrete with Mild Steel Lathe Waste fibre showed percentage increase of 39.1%, 20.4% and 65.1% respectively.
2. When compared with the values of conventional concrete the Flexural strength of concretes reinforced with Steel Filings, concrete with fibres Beverage tin and concrete with Mild Steel Lathe Waste fibre showed percentage increase of 6.65%, 31.42%, and 23.86% respectively.
3. When compared with the values of conventional concrete the Split tensile strength of concretes reinforced with Steel Filings, concrete with fibres Beverage tin and concrete with Mild Steel Lathe Waste fibre showed percentage increase of 35.51%, 11.96% and 38.77% respectively.
4. The initial cracking load values for deep beams with openings cast with concrete reinforced with Steel Filings, concrete with fibres Beverage tin and concrete with Mild Steel Lathe Waste fibre showed increases of 5.83%, 2.5% and 4.16% respectively.
5. The ultimate load values for deep beams with openings cast with concrete reinforced with Steel Filings, concrete with fibres Beverage tin and concrete with Mild Steel Lathe Waste fibre showed increases of 6.88%, 3.75% and 6.25% respectively.
6. When compared with conventional concrete the fibre reinforced concrete exhibited higher performance characteristics.

V. Acknowledgement

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