# An Experimental Investigation On Effect Of Openings In Rc Deep Beams

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**Abstract.** Transfer beams in coastal projects and foundations, bunker walls, and load-bearing walls in buildings are all popular applications for reinforced concrete deep beams. Openings in such beams are required to enable doors and windows, as well as equipment such as ventilation ducts and air conditioning systems. The deep beams with openings would reduce its shear capacity, posing a major safety issue. Only a few investigations onbehavioral aspects and capacity of deep RC beams with openings have been published. Because such openings are unavoidable, adequate reinforcing measures must be adopted to compensate for the loss of strength. The purpose of this experiment is to investigate deep beams with various types of openings. Casting and testing of three deep beams with openings under a two-point load. The sample has a 150mm x 500mm cross section and an overall length of 1.2 m. There are two openings in each beam and they are symmetrically placed around the mid span of the beam, one in each shear span.The percentage decrease in the ultimate load of thelong square-opening girder is 4,032% compared to the long round-opening girder. Deep beams with square and circular openings failed due to shear and exhibited shear cracks.

**Keywords:** Deep Beams, Reinforced Concrete, Openings.

## 1 Introduction

Clause 29 of IS 456:2000 code of practice states that a simply supported beam with L/D less than 2 shall be classified as deep beam. RC Continuous beams shall be considered deep, if the L/D ratio is less than 2.5. The effective span is either 1.15 times the free span or the centre to centre distance between the supports, whichever is less.When compared to pure bending, this causes the strain distribution to be non-linear and the shear strains to be substantial. Strength of deep beam is regulated by shear rather than bending due to their proportions. Mechanical and electrical connections, as well as passageways such as door and hallway openings in structures, frequently necessitate large holes through deep beams. For window and door installations, as well as the passage of utility lines and vents, deep beam openings may be desirable. The height of the building floor can be decreased by allowing tunnels in deep beams for utility facilities.

Basil Mathew [1] proposed a methodology for constructing three-dimensional non-linear FEM (Finite Element Model). For deep beams with web holes and basalt fibre reinforced polymer (BFRP) composites externally attached. A total of sixteen finite element models were investigated. There were 180 x 180mm and 120 x 120mm square holes, as well as

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160mm and 100mm diameter circular openings. The shear strength of the beam decreased as the opening size grew larger, regardless of shape.

SiewChoo Chin et al. studied the behavior of RC deep beams with large circular openings and the openings that were reinforced with externally bonded CFRP composites in shear under four point loading. A total of three beams of 35 MPa design strength have been tested till failure.Researchers employed a deep beam withoutopening and two numbers of deep beams with enormous circular openings to evaluate the behavior of control and beams strengthened using CFRP wrap. The deep RC beam with large circular openings in the shear zone revealed a significant loss of strength while compared to the original strength of the control beam, with a reduction of 51 percent. The surface strengthening strategy could only recoup 56 percent of the beam capacity when compared to the control beam.

## 2 Materials Used

### 2.1.Cement

The concrete is made up of 53 grade Ordinary Portland Cement (OPC), The specific gravity of the cement is 3.15.

**Table1CharacteristicsofOPC 53 grade cement**

| **S.No** | **Characteristics** | **Results obtained from Laboratory Experiment** |
|---|---|---|
| 1 | Standard Consistency | 32 percentage |
| 2 | Settingtime( Initial) | 345 minutes |
| 3 | Setting time(Final) | 510 minutes |

### 2.2 Fine Aggregate

According to IS 383:2016, the fine aggregate utilized was clean dry M Sand with a size of in4.75mm and a fineness modulus of 2.26 in grading zone II.

**Table 2 Physical Characteristics ofM Sand**

| **S.No** | **Characteristics** | **Laboratory test Results** |
|---|---|---|
| 1 | Specific Gravity(SG) | 2.734 |
| 2 | Water Absorption(WA) | 2.805 % |

### 2.3 Coarse Aggregate

The coarse aggregate conforming to20mm size category and with a fineness modulus of 7.12wereusedfor mix design and casting.

**Table3 Physical Characteristicsof Gravel (CA)**

| S.No | Characteristics | Laboratory test Results |
|---|---|---|
| **1** | Specific Gravity(SG) | 2.886 |
| **2** | Water Absorption(WA) | 0.4 % |

### 2.4Water

Water, the most significant component in concrete manufacturing, is employed in the precise amounts because it regulates many of the fresh and hardened concrete qualities, such as workability, compressive strength, drying shrinkage, and cracking.

## 3. PROPORTION OF CONCRETE MIX

The material requirements and mix proportion for one cubic metre of M25 Grade of concrete designed as per IS 10262:2009 is given below

Weight of Cement = 383 kg
Weight of Water = 192kg
M Sand = 713.5 kg
Gravel(Coarse Aggregate)= 1229kg
W/C( Water-Cement) ratio =0.5
Mix ratio =0.5: 1: 1.86: 3.206

## 4 Tests On Hardened Concrete

### 4.1 Cube Compression Test

The average of strengths of the three cubes of 150 mm side is considered to obtainthe 28 days strength of concrete.

**Table 4 Compressive strength test results of Cube**

| Sl.No | Load (t) | Compressive strength( $N/mm^2$) |
|---|---|---|
| 1 | 61 | 26.59 |
| 2 | 62 | 27.03 |
| 3 | 64 | 27.90 |

The average compressive strength is 27.17$N/mm^2$.

### 4.2 Split-Tension Test

The strength of three plain concrete cylindrical specimens of 150 mm diameter and 300 mm height is used to evaluate the 28-day split tensile strength of concrete.

**Table 5 Split Tensile StrengthTestresults**

| Sl.No | Load (t) | Split Tensile strength ( $N/mm^2$) |
|---|---|---|
| 1 | 17 | 2.35 |
| 2 | 15 | 2.08 |
| 3 | 18 | 2.49 |

The average split tensile strength is 2.31$N/mm^2$.

### 4.3Modulus of Rupture (Flexural tensile strength)Test

Three plain concrete prisms of 100 mm x 100 mm section and 350 mm span are cast and tested to establish failure load in flexure. The flexural strength is calculated by taking the average of the strengths of the three prisms.

**Table 6 Results of Flexural Strength Test**

| S.NO | Load (kg) | a (mm) | Flexural strength( $N/mm^2$) | Average flexural strength( $N/mm^2$) |
|---|---|---|---|---|
| 1 | 1820 | 123 | 6.24 | 6.08 |
| 2 | 1770 | 136 | 6.07 | |
| 3 | 1720 | 148 | 5.90 | |

## 5 Testing Of Deep Beams

### 5.1 Test specimen

The beams are cast and have a cross section of 500mm x 150mm and a length of 1200mm. Square openings sized 150mm x 150mm and round openingssized 150 mm diameter are located symmetrically about the mid depth and at 225 mm from the mid-span of the beam.The reinforcements for the deep beams are shown below

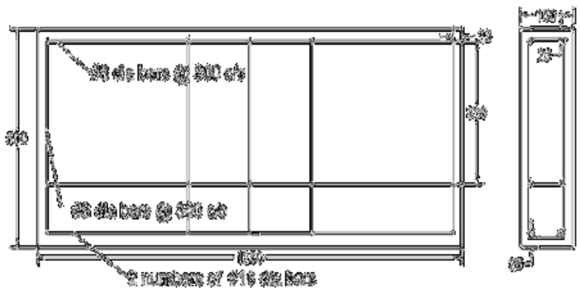

**Figure1Reinforcement Detailing for Deep Beam without Opening**

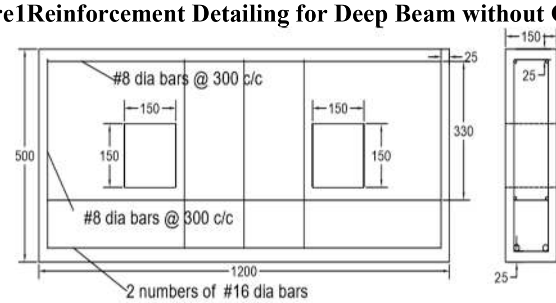


**Figure 2 Reinforcement Detailing for Deep Beam with Square Openings**

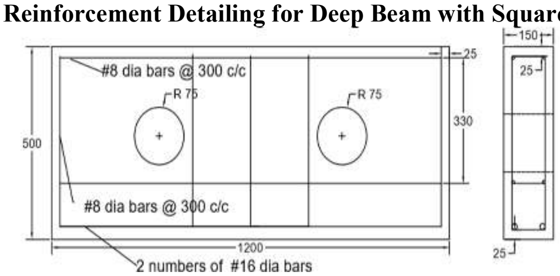


**Figure 3 Reinforcement Detailing for Deep Beam with Circular Openings**

**5.2 Test Set-up**

With a 1050mm effective span and 350mm shear span, the beams were tested under a two-point load. The two point loads were 350 mm apart and symmetrically spaced from the mid-span of the prism. At the bottom of the beam an LVDT (linear variable displacement transducer) is installed monitoring the deflection in the center of the span

**Figure 4Two Point Loading arrangement for Deep Beam without Openings**

**Figure 5 Two Point Loading of Deep Beam with Square Openings**

**Figure 6.Two Point Loading of Deep Beam with Circular Openings**

### 5.3 Results and Discussions

#### 5.3.1 DeepBeam without Opening

The first crack occured at a 270 kNload with a deflection of 2.18 mm.

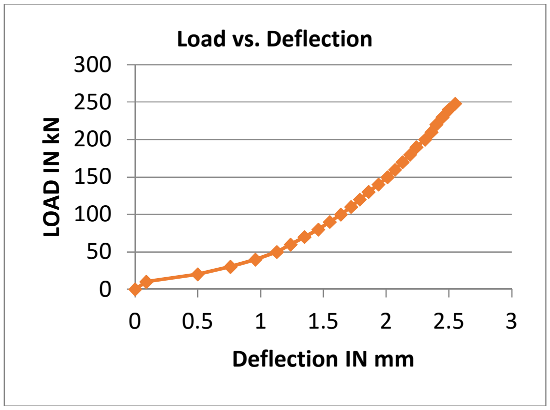


**Figure 7Load Deflection Behavior of Deep Beam control specimens**

### 5.3.2 Deep Beam with Square Openings

The first crack appeared under a load of 90 kN and a 1.93 mm deflection. As the load continued to increase, crack propagation continued and the beam failed at 238 kN with a maximum deflection of 5.15 mm.The deep beam with square openings failed by shear showing shear cracks within the shear span and no flexural cracks were found.

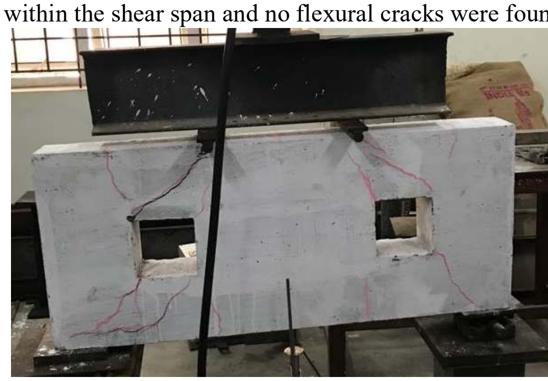

**Figure 8 Crack Pattern Observed in Deep Beam with Square Openings**

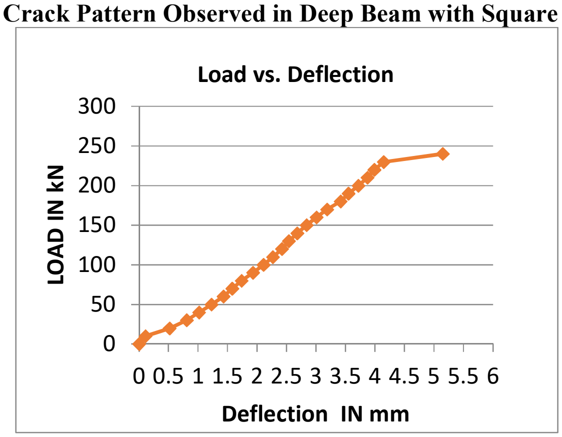


**Figure 9 Load Deflection Behaviorof Deep Beam with Square Openings**

#### 5.3.3 Deep Beam with Square Openings

With a deflection of 2.36 mm, the first crack appeared under a load of 130 kN. The crack widened as the load rose, and the deep beam failed at 248 kN with a maximum deflection of 5.84 mm.The deep beam with circular openings failed by shear and showed shear cracks within the shear span region and no bending cracks were found.

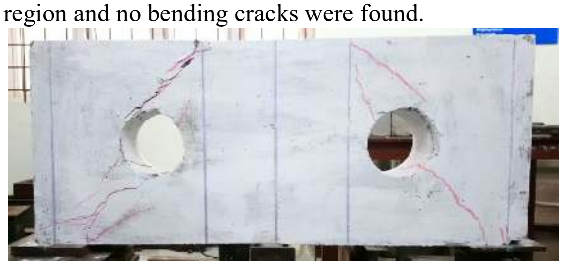

**Figure 10 Crack Pattern Observed in Deep Beam with Circular Opening**

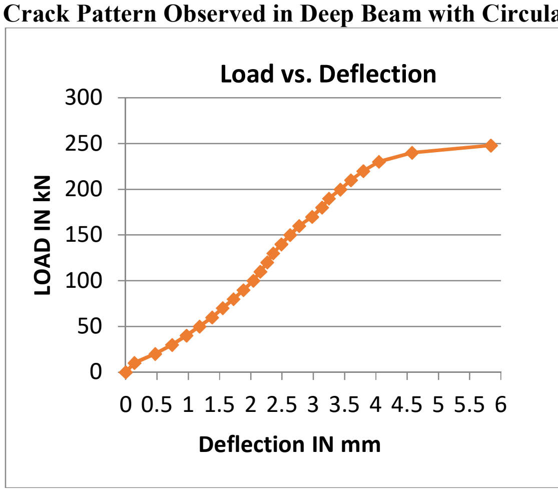


**Figure 11 Load Deflection Behavior of Deep Beam with Circular Openings**

## 6 Conclusions

An experimental examination of the effect of square and circular openings on the behavior of RC deep beams is presented in this research paper. From the findings and discussions, the following conclusions were drawn:

- The percentage decrease in the first crack load of the deep beam with square opening is 66.67% when compared with the conventional beam.
- The percentage decrease in the first crack load of the deep beam with circular opening is 51.85% while compared with the first crack load of deep beam without openings.
- The maximum load of RC deep beam with a square opening is reduced by 4.032 percent while compared with the maximum load ofRC deep beam with a round

opening. Shear cracks appeared in deep beams with square and round holes due to shear failure.

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