Numerical Study on The Shear Behavior of RC Deep Beams with Longitudinal Hole

Elias Thomas Kalloor
Dept. of Civil Engineering
Saintgits College of Engineering
Kottayam, India

Alice Johny
Dept. of Civil Engineering
Saintgits College of Engineering
Kottayam, India

***Abstract*— Deep beam is a structural member whose behavior is dominated by shear deformation. The exact analysis of deep beam is complex and the presence of longitudinal hole aggravates the situation. This paper presents numerical studies carried out to determine the most suitable position of longitudinal hole in a deep reinforced concrete beam. In order to investigate the effect of longitudinal hole in RC deep beams, a deep beam with dimension 1000*200*450mm (L*B*D) was modelled and analysed under uniform loading and simply supported conditions. The same beam was then analysed by varying the position of circular longitudinal opening. Analysis was carried out using ANSYS software. From the analysis, load deflection characteristics of hollow deep beams were obtained and compared with solid RC deep beam. The results showed that the deep beams with longitudinal opening had undergone more deformation when compared with solid deep beam. The optimum position of longitudinal circular opening in deep beams had also been obtained from the analysis.**

***Keywords*— slope, rainfall intensity, pore-water pressure, displacement**

I. INTRODUCTION

Nowadays research efforts are continuously looking for new, better and efficient construction materials and methods. Recently, the problem faced by the construction industry is acute shortage of raw materials. Concrete materials are still a dominant material for construction due to its advantages such as workability, low cost and fire resistance as well as its low maintenance cost. Concrete is weak in tension and strong in compression. Various attempts have been made to reduce the weight of structure by removing concrete from tension zone of RC beams. This unutilized portion of concrete in beams is called as the sacrificial concrete. Studies have proven that the removal of concrete from the tension zone of RC beams hasn't affected the strength of beam.

In deep beams, the stress distribution is no longer linear as in normal beam theory. Hence a transverse section which is plane before bending will not remain plane after bending. And also the shear deformation becomes significant compared to flexure in RC deep beams. Here an attempt is done to reduce the self-weight of a RC Deep Beam removing the concrete from deep beam in the longitudinal direction. Main objective of the study is to analytically fix the position of longitudinal hole in deep beam and to study the percentage of strength reduction when compared with solid deep beam. Structural material optimization can reduce the dead load which reduce the contribution of seismic effect in high rise structures and also very good at the vibration dampers and heat isolation.

Numerous experimental studies have been carried out to study the behaviour of deep beams. Most of which concludes that in deep beams, the failure is mostly controlled by its shear capacity. Therefore shear strength has prime importance in deep beams. Shear property of deep beam is still considered to be a complex problem. Based on former studies, in deep beams the load has been transferred to the support through the concrete struts due to the formation of arch action, hence resulting in high shear strength. Deep beams also can be considered as simple truss as the reinforcement acts as tie. Earlier studies have also proven that as the depth of deep beam increases shear action results in sudden shear failure. The propagation of cracks in larger size deep beam is much faster than in smaller size deep beams and they show a brittle failure.

A. Scope

- The optimum position of longitudinal hole in deep beams can be analyzed.
- Provision of longitudinal hole in deep beams can result in material optimization and also can reduce the self-weight of structural member.
- Presence of longitudinal hole in RC deep beam can reduce the shear strength capacity of deep beam and the percentage reduction in strength characteristics shall be found out

II METHODOLOGY

The ANSYS software was used for analysis of specimens. Validation was done as per journal. The deep beam was designed as per IS 456:2000. The dimensions of the deep beam were 1000mm X 200 mm X 450mm. The specimen was provided with 2 numbers of 16mm diameter bars as the tension reinforcement, 2 numbers of 12mm diameter bars as the hanger bars, 8mm diameter bars were provide as vertical shear reinforcement at spacing of 300mm c/c, 2numbers of 8mm diameter bars were provided as horizontal shear reinforcement. The reinforcement detailing used for modeling is shown in figure 1. The longitudinal holes were provided at various positions below the neutral axis of the deep beam. The maximum depth of neutral axis was obtained as 188.14mm from eqn-1.

$$\text{Neutral axis depth: } \frac{X_{u,max}}{d} = 0.46 \qquad (1)$$

$$X_{u,max} = 188.14mm$$

Seven deep beam specimens were modeled and analyzed. One control specimen (solid specimen) and others with longitudinal holes at various positions below the neutral axis of the beam were modeled. The details of different deep beam specimens and their symbols are described in the table 1 shown below. The deep beams were simply supported on two edges. Load of 70MPa was applied on the specimens and corresponding total deformations were found out. Static structural analysis was done. Then comparison of results was carried out.

TABLE I. DETAILS OF DEEP BEAM SPECIMENS

S.No	Symbol	Nomenclature
1.	D	Control deep beam
2.	D125	Deep beam with 70mm dia. longitudinal hole at 125mm from bottom of beam
3.	D150	Deep beam with 70mm dia. longitudinal hole at 150mm from bottom of beam
4.	D175	Deep beam with 70mm dia. longitudinal hole at 175mm from bottom of beam
5.	D200	Deep beam with 70mm dia. longitudinal hole at 200mm from bottom of beam
6.	D225	Deep beam with 70mm dia. longitudinal hole at 225mm from bottom of beam
7.	D250	Deep beam with 70mm dia. longitudinal hole at 250mm from bottom of beam

III MODELLING

Longitudinal hole provided in hollow RC deep beam is having diameter of 70mm. Six hollow deep beam specimens and a solid deep beam control specimen was modeled. The hollow specimens were modeled with holes at varying positions below the neutral axis of the deep beam. The material properties used are shown in table 2. The geometry and meshing of deep beam model D specimen is shown in figure 1 and 2 respectively.

Table 2. Material properties provided

Sl. No.	Material	Young's Modulus (E) in GPa	Poisson's Ratio
1	Concrete	25	0.15
2	Steel	200	0.30

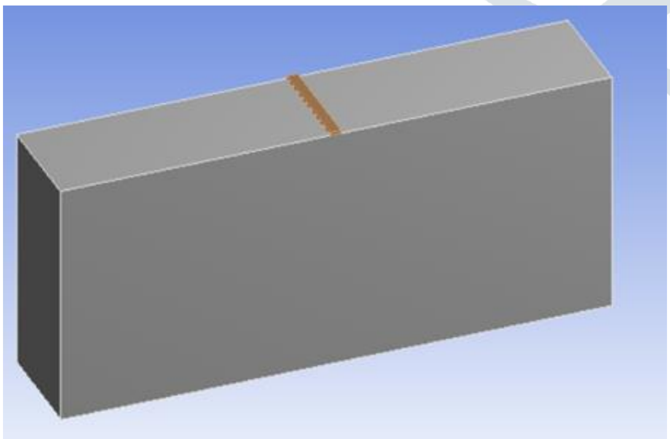

Fig 1.Geometry of D specimen

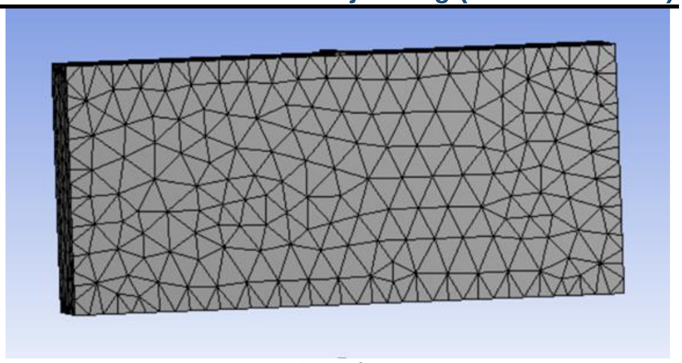

Fig 2. Meshing of D specimen

The deep beams were simply supported on two edges. The effective length was taken as 690mm after proper design consideration from IS 456:2000. Loads were applied as pressure of 70MPA. Loading and support conditions were similar for all the deep beam specimens. Figure 3 shows the loading on deep beam specimen simply supported on two edges. The reinforcement detailing used for modeling is shown in figure 4.

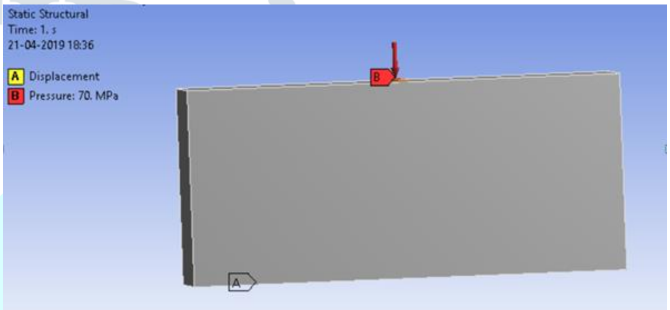

Fig 3. Loading and support condition of D specimen

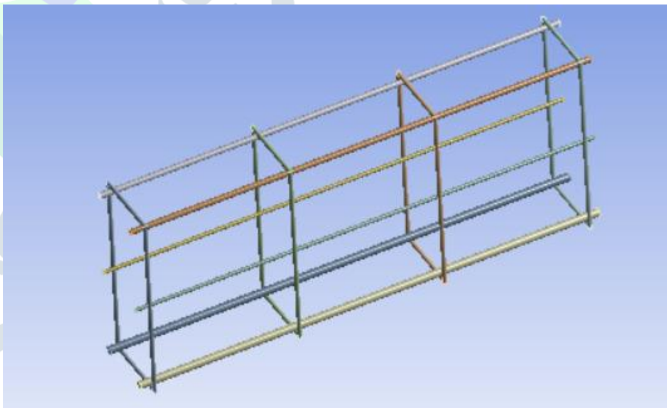

Fig 4 Reinforcement details of model

IV. RESULTS OBTAINED

Static structural analysis was done. Loads of 70MPa was applied in all specimens including control and hollow deep beams and corresponding total deformations were found out. Percentage decrease in deformation of different specimens compared to control deep beam is shown in Table 3. Total deformation in D specimen control specimen and that of D225 specimen is shown in figure 5 and 6 respectively.

Specimen	D125	D150	D175	D200	D225	D250
Decrease in deformation compared to control slab (%)	27.26%	23.63%	19.12%	14.5%	6.3%	12.73%

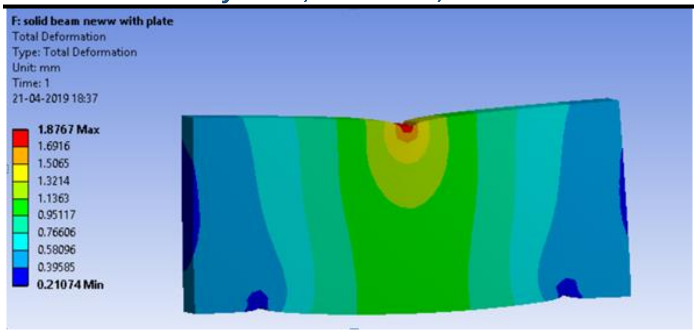

Fig 5.Deformation of D(control specimen)

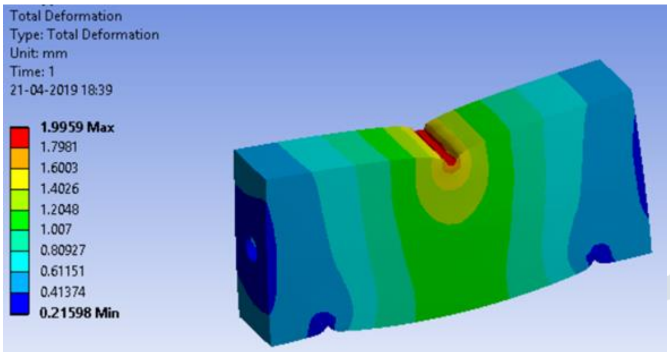

Fig 6. Deformation of D225 specimen

V. CONCLUSION

The deep beam specimens with longitudinal holes at varying depth and a control deep beam specimen (solid) are analyzed under the specified loading condition. The results of different hollow deep beam specimens are compared with control slab and concluded as follows:

- The deformations of each deep beam specimens under the given loading condition showed similar pattern.
- On comparison of deformation of hollow specimens, D225 showed least deformation.
- The percentage increase of deformation of hollow specimen when compared with solid specimen was obtained and the D225 specimen showed the better performance among the hollow specimens.
- The best suitable position of longitudinal hole is 200mm from bottom of deep beam

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