RESEARCH ARTICLE OPEN ACCESS

Study on Flexural Behaviour of Perforated Beam

Roshna A V [1], Anitha Babu [2]
Department of Civil Engineering
Vimal Jyothi Engineering College, Kannur
India

ABSTRACT
Beams with perforations in building are necessary for the passage of utility ducts. The current paper presents an experimental study in order to verify the flexural performance of a new developed perforated beam system. Three perforations sizes were studied having perforation diameter 25mm, 40mm and 50mm. These three perforated beams along with one solid reference beam were prepared and configured then tested under loading frame till complete collapse. The position of the beam, cross section of the beam, the amount of longitudinal steel, and the transverse steel of the beam are kept constant. The influence of the hole on the strength of the beams is studied by taking into account the size of hole. Test results indicate the specimen with small sized perforations showed approximately the same flexural capacity as that of the solid beam. While perforated beam with larger sized perforations showed lower performance as that of solid beam. Increase in the size of the hole resulted in a decrease in first crack load and ultimate load. Savings would not be significant, in the case of small buildings. But in the case of high rise building savings in a single storey multiplied by no.of stories would result in substantial saving in cost of construction.

Keywords :— Flexural Behaviour, Perforated Beam, Loading Frame.

I. INTRODUCTION

Nowadays research efforts are continuously looking for new, better and efficient construction material and method. . In recent days the problem faced by the construction industry is acute shortage of raw materials. so it is our responsibility to reduce the usage of these raw materials. In case of simply support reinforced concrete beam, the region below neutral axis is in tension and above neutral axis is in compression .and we know that the flexural capacity of the beam is influenced only by compression stresses of the concrete and the tensile stress of the steel reinforcement. . Efficient use the concrete materials can be done by replacing the concrete in and below the neutral axis. Provision of transverse hole in beams results in the reduction of the self-weight of beams. Consequently, the required size of other structural members that support these beams, such as columns and foundations, are reduced, leading to savings in construction materials. In addition, there is scope for taking essential utility services, such as water supply sewage, air-conditioning ducts, and electrical and telephone cables, through the transverse holes of these beams, wherever necessary .Although a wealth of information is available on the flexural strength of solid RC beams, a satisfactory amount of information is not available on the flexural strength of hollow RC beams having transverse holes. Studies were conducted beams with longitudinal hole in and below and above the neutral axis. The size of hole also varied and they conclude beam with hole below neutral axis and smaller sized hole is shows better performance. Similarly for longer beams with transverse holes also under taken and they proved that smaller sized perforations with cross bars around the perforations are better. But limitted information is available about perforated beams with smaller sized perforations. In the current study, a new perforated beam system is developed and tested. Hence, an attempt has been made in this project to study the behavior and strength of perforated RC beams by providing small transverse holes with different diameter. Three perforated beams along with one solid beam is cast and tested in order to verify flexural performance of perforated beam.The need of the project is to innovate a new construction technique which will reduce weight and cost of the reinforced concrete structures by replacing the concrete below neutral axis. This is an alternative to reduce the use of concrete. Sustainability can be achieved by replacing the partially used concrete.

II. EXIPERIMENTAL PROGRAMME

A. *Test Specimen*

The current paper presents an experimental study in order to verify the flexural performance of a new developed perforated beam system. This system facilitates passing the pipes of utility services through its perforations as well as it has a good-looking appearance. Therefore, three perforations sizes were studied having perforation diameter 25mm, 40mm and 50mm .Accordingly four perforated beams along with one solid reference beam were prepared and configured then tested under repeated loading till complete collapse.

Table 1.Details of beam casted

Serial number	Designation of Beam	Diameter of perforated beam(mm)	Date of cast	Date of test
1	BC	0	25/10/2017	22/11/2017
2	BP-D25	25	4/1/2018	31/1/2018
3	BP-D40	40	12/1/2018	8/2/2018
4	BP-D50	50	27/1/2018	23/2/2018

The control beam of cross-sectional dimensions of 150 mm width by 230 mm total depth. The total span of the beams was 2000 mm. The flexural reinforcement of all beams consisted of two deformed steel bars of 12 mm diameter in the tension side and two deformed steel bars of 10 mm diameter in the compression side. Perforated beam of 25mm diameter consisting 11 number of perforation in between the 12 number of stirrups and casted and cured for 28 days. The same reinforcement is used in all perforated beams. Perforated beam of 40mm and 50mm perforation sizes also made in similar way. For making transverse holes, frictionless PVC pipe of a predetermined external diameter was placed in between the stirrup in correct position before casting . The distance from the center of the hole to the top surface of the beam 155mm.

*B. **Material test and properties***

The concrete mix used for casting all tested beams was made Using Portland pozzolana cement, fine aggregate (Msand conforming to zone III, as per Indian Standards), and Coarse aggregate having a maximum size of 20 mm. The mix Proportion by weight was 1:1.67:3.67 for M20-grade concrete, and steel bars of Fe515 grade were used for this investigation.The bottom reinforcement in each of the beams was of two bars 12 mm in diameter, whereas the top reinforcement consisted of two bars 10mm in diameter.

Fig .1Reinforcement and perforation configuration of perforated beam

a) Beam BP-D25

b) Beam BP-D40

c) Beam BP-D50

Fig .2 casting of beams

C. Test Setup

The experimental work program has been conducted .In order to trace the deflected shapes of all beams, LVDT were used. Each beam was loaded by using distributed beam. Thus, the beams were loaded incrementally up to complete collapse. The loads on the beams were measured by a load cell of 200 kN capacity. After each loading step, the vertical deflections were recorded.

The control specimen and beams with various perforation were whitened for better observation of the development of cracks. The specimens were simply supported and subjected to two point load. Linear variable differential transducers (LVDT) were placed at center bottom and at support in point of the beam bottom. LVDTs are used to measure the displacement of the test specimen. The measured displacement will be displayed in the digital indicator and further it is connected to Data Acquisition system. The load is applied at each step and continued until failure. To measure the load applied to the specimen, compression type load cell was used. The failure load was defined as a load that caused the specimen to fail in flexure or that caused failure at the interface between the substrate and overlay.

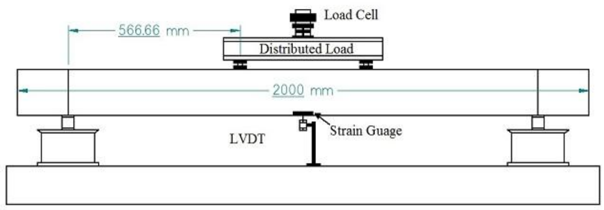

Fig .3 test setup

III. RESULT AND DISCUSSION

The control beam of 2000mm length and 150mm breadth and 230mm depth casted. Compacted and finished and cured properly for 28 days. After the curing time it is tested under loading frame. Similarly the other specimens that are 25mm diameter perforated beam 40mm diameter perforated beam and 50mm diameter perforated beam is casted .Perforated beam of 25mm diameter also tested under loading frame.

Table 2.testing result

Serial number	Beam designation	First cracking load (kN)	Ultimate load(kN)	Deflection (mm)
1	BC	34	69	15.31
2	BP-D25	32	67.6	18.53
3	BP-D40	22	65.2	20.23
4	BP-D50	19	63	21.74

A. *Mode of failure*

According to the loading scheme, all beams started to show flexural cracks at the middle part of the span and with further loading, flexural cracks began to be distributed around the middle part and increased in their lengths and widths. In the sequel, flexural shear cracks were developed and finally shear cracks were formed. all beams were failed by flexural mode of failure. The solid beam BC started to crack due to flexure at the mid span section at a vertical load of about 34 kN, which is about 50.7% of the failure load. Proceeding with loading, the flexural cracks spread at the tension side till a vertical load of about 69kN, and then shear cracks began to appear

B. *Cracking and Ultimate load*

From table 2 the first cracking load of control beam is greater than that of other perforated beams. it can be observed that providing perforations accelerated the appearance of cracks due to flexure compare to those of the solid beam. From table we can observe that the beam with larger sized perforations show cracking earlier than beam with smaller sized perforations. it was noticed that the perforated beams were began to crack at smaller load than that of the solid beam BC. That could be attributed to the reduction on the concrete section. The cracking loads of beams BP-D25, BP-D40 and BP-D50 were 32kN, 22kN and 19kN. All cracks were continued through the edges of the perforations. Regarding the ultimate load it was noticed that the ultimate load of control beam were Approximately same as that of BP-D25.The ultimate load of beams BC,BP-D25, BP-D40 and BP-D50 were 69,67.6,65.2 and 63KN. It can be observed that the perforated beams BP-D25 exhibited approximately the same ultimate load as that of the solid beam .This means that the considered perforations did not affect the flexural performance of the beam.

a)Beam BC

b) Beam BP-D25

c) Beam BP-D40

d) Beam BP-D50

Fig.4 Crack mapping on longitudinal section of beams

C. *Load Vs Deflection relationships*

Maximum load that the control beam can carry is found to be 69kN with maximum central deflection of 18.53mm. In the same way, for the case of beam with 25mm size perforations the maximum load is found to be 67.6kN and the central deflection is 15.31mm at that particular load. In the same way for the case of perforated beam with 40mm diameter the maximum load is found to be 65.2 kN and the central deflection is 20.23mm.and the maximum load that the beam with 50mm diameter perforations can carry is 63KN and the central deflection is 21.74mm.

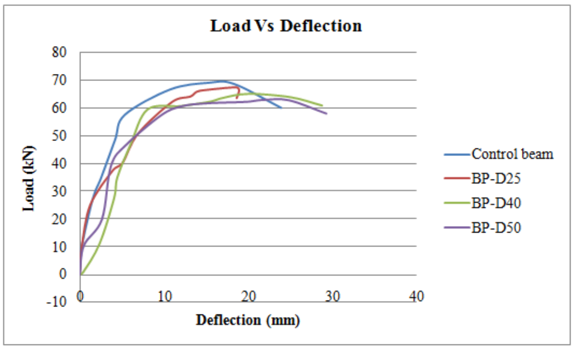

Fig .5 Load Vs deflection graph

All test beams were passed through two point loading. It can noticed that from the recorded value the highest permanent deflection is attained by beam with 50mm perforation sizes while the lowest deflection is achieved by beam with 25mm perforation sizes. The solid beam BC as well as all perforated beams showed almost the same behaviour at the beginning till the initiation of first flexural crack and then significant variations started to be observed. With further loading, flexural cracks began to propagate in the tension side and around the perforations, while more cracks were concentrated under perforations. Hence, the deflection began to increase as a result of decreased stiffness.

D. *Efficiency of proposed perforation system*

Table 3.Efficiency Of Proposed Perforation System

SI NO	BEAM	CONCRETE LOSS(%)	SELF WEIGHT REDUCTION (KG)	ULTIMATE LOAD LOSS (%)
1	BC	0	0	69
2	BP-D25	4.69	8.109	2.02
3	BP-D40	12.02	12.02	5.50
4	BP-D50	18.78	18.78	8.69

Providing perforations in the reinforced concrete beams has shown significant effect on ultimate load carrying capacity. Table 3summarizes the gain/loss in both ultimate capacity for all perforated beams compared to those of solid beam. Obviously, it is a challenging issue to obtain the most favourable characteristics of the perforated beam allowing easy passage ways for facility services and keeping the good-looking appearance with a minimal cost

a) Beam BP-D25

b) Beam BP-D40

c) Beam BP-D50

Fig .6 first crack mapping of perforated beams

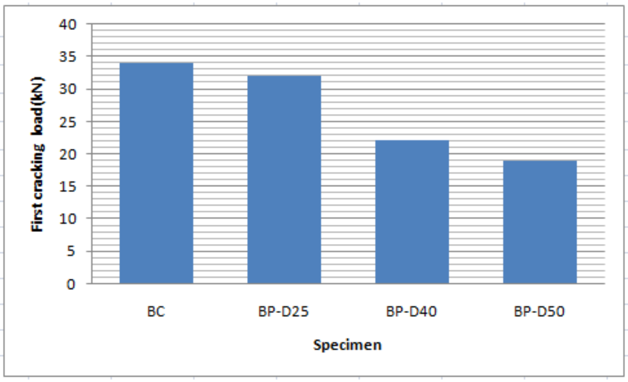

Fig.7first crack comparison

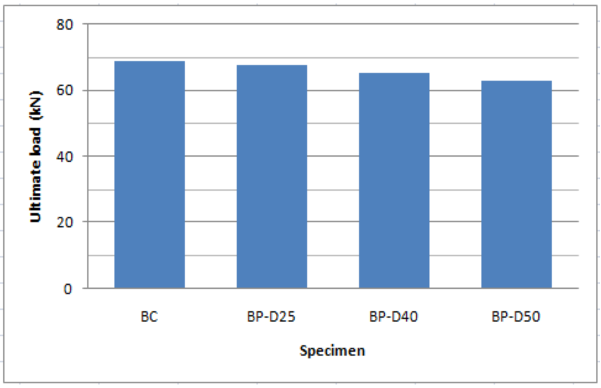

Fig.8ultimate load comparison

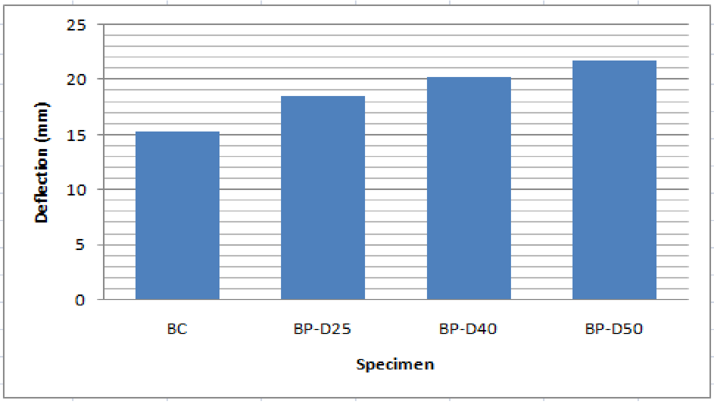

Fig.9 deflection comparison

IV. CONCLUSION

Based on the adopted concrete dimensions, perforations sizes as well as the considered loading scheme and history, the following conclusions could be highlighted. The cross section of the beam, and the amount of longitudinal and transverse steel in the beam, were kept constant. The same M20 grade of concrete was adopted in all the beams.

1. The maximum load for control beam is 69kN.and centre deflection of that particular load is 15.31mm
2. The maximum load that Perforated beam of 25mm perforation size the Can carry is 67.6KN with 2.02% decrement with central deflection is 18.53mm.
3. Ultimate load carrying capacity of perforated beam of 40mm diameter is 65.2 KN with 5.50%decrementandcorresponding deflection is 20.23mm.
4. Ultimate load carrying capacity of beam with 50mm size perforations is 63KN with 8.69% decrement with 21.74mm central deflection.
5. Increase in the size of the hole resulted in a decrease in first crack load and ultimate load.
6. By reducing 4.69% concrete and 8.109 kg weight ,the perforated beam of 25mm size perforations can take 67.6 kN load.
7. It could be concluded that the perforated beams of 25 mm perforations diameter showed approximately the same flexural capacity as that of the solid beam.

REFERENCES

[1] **Ahmad Jabbar Hussain Alshimmeri , HadiNasir Ghadhban Al-Maliki** (Jul 2014)"Structural Behavior of Reinforced Concrete Hollow Beams under Partial Uniformly Distributed Load" International Journal of Engineering, Vol.20, PP:130-145.

[2] **Anuja Mary Kuriakose, Mathews M. Paul**(Oct 2015) " Behaviour Of Beams With Low Grade Concrete Or Hollow Neutral Axis Zone" International Journal of Civil Engineering and Technology, Vol.6, PP:185-190.

[3] **Anju Varghese , Basil.M.Joseph** (Aug2016) "Experimental and Numerical Studies on Reinforced Concrete Hollow core Sandwich Beams" International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 8, PP:17430437.

[4] **ArunMurugesan,andArunachalamNarayanan**,(2016) "Influence of a Longitudinal Circular Hole on Flexural Strength of Reinforced Concrete Beams". American Society of Civil Engineers.

[5] **Aswathy S Kumar, Anup Joy** (Aug 2015)"Experimental Investigation on Partial Replacement of Concrete Below Neutral Axis of Beam" International Journal of Science and Research, Vol . 4, No:8, PP: 1670 .

[6] **Daniel JJ, Revathy DJ**. (2014)"Experimental investigation on flexural strength of beams with opening". Int J Res Manage Tech (IJRMT) 2014; 4:141–3. 1674.

[7] **Dhinesh , Satheesh**(2015) Flexural Behaviour of Hollow Square Beam *International Journal of Scientific Engineering and Applied Science (IJSEAS)– Volume-3, Issue-3,March 2017ISSN: 2395-3470.*

[8] **Dr.G.HemalathaandW.GodwinJesudhason** (2013), ―Experimental Investigation on Beams Partial Replacement Below the Neutral Axis‖, *International Journal of Civil and Structural Engineering Research,*Vol. 2, January

[9] **Jain Joy1 Rajesh Rajeev**(2014) "Effect of Reinforced Concrete Beam with Hollow Neutral Axis "*IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 10, 2014 | ISSN (online): 2321-0613.*

[10] **.A. Mansur** " (2011)Design of reinforced concrete beams with web openings "Structural Engineering and Construction Conference (APSEC2006),Vol.6,pp.

[11] **Nibin Varghese, Anup Joy** (May 2016)"Flexural Behaviour of Reinforced Concrete Beam with Hollow Core at Various Depth" International Journal of Science and Research(IJSR), Vol.5, PP:741-746.

[12] **Samar Gohar, Hamdy M. Afefy , Nesreen M. Kassem, Salah El Din F. Taher**,(2017)" Flexural performance of self-compacted perforated concrete beams under repeated loading" science direct, Engineering Structures 143,441–454.

[13] **MitaAnn Zachariah, Sunitha A Daniel**(Sep 2016) "Experimental Analysis of Flexural Behaviour and Crack Pattern of RCC Composite Beam" International Journal of Science Technology & Engineering, Volume 3,Issue 03, PP: 58-65.

[14] **Rohit Vyas, Dr.Sanjay kulkarni, Nikhil Landge**(2017)," experimental investigation of reinforced concrete beam with opening for combined bending and shear" International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 06.

[15] **IS: 2386 (part III) 1963**; Methods of Test for Aggregates for Concrete.

[16] **IS: 10262 2009.**

[17] **IS 456 2000;** Plain and Reinforced Concrete-Code of Practice.

[18] **IS: 383-1970**; Specification for Coarse and Fine Aggregate from Natural Sources for Concrete.