Analytical Study on Shear Behavior of Reinforced Concrete Beam with Varying Shapes of Web Opening

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***Abstract*— Reinforced concrete beam with transverse web opening is a facility that allows the services such as telephone lines air conditioning and ventilating ducts, to pass through the structure. Because of the change in the beam section the corners of the opening are subjected to large concentration of stress, possibly producing oblique cracks in the beam. The region nearby the openings are measured as the weaker part of the beam. Therefore, a decline in bearing capability and also a change in the load transport mechanism is experienced. This thesis investigates the analytical study on the influence of various opening shapes with constant area on shear behaviour of RC beams without extra shear reinforcement around the opening. In this thesis nonlinear analysis using ANSYS 18.1 is used to analyze the beam.**

Keywords*— Opening shape, Shear capacity, Reinforced concrete beam, Finite element analysis

I. INTRODUCTION

The RC beam with opening is a method that permits the services to move towards the construction. Due to rapid changes in the beams cross-section, the edges of the opening stimulate crosswise cracks and can be subjected to high stress concentrations. The reliability and constancy of the beam will then be considered compromised, and the regions nearby the opening is the weakest element of the beam. Therefore, a decline in the bearing capability and also a change in the load transport mechanism is experienced. If safety actions are not in use, preventable accidents are likely to ensue.

An opening in beam changes their easy behavior to a difficult one and thus causing serviceability problem. Cracks that grow near the opening reduce the load carrying capacity ability of the beams. The opening leads to the disturbances in the continuous flow of stresses and this produces early cracks in the opening region. Hence it is very necessary to learn the result of opening on the beams so that it can be given as structural element without reducing their carrying capacities.

Sufficient attention and treatment is needed, for the reliability and constancy of the structure with shear openings. Since there is no advance warning before the shear failure, it will be of catastrophic in nature. The breakable nature of the concrete structure as its intensity Several methods are used to strengthen the structural members, they include external wrapping of FRP and also strengthen using various fibrous materials. FRP which is light weight ,due to its superb mechanical strength and being highly resistive to the corrosive nature of aggressive materials under wide range of temperature is a good substitute for the conventional steel reinforcements in RC structures.

The web openings are classified based on their size and positions. Web openings have been found in various shape such as elliptical, circular, square, rectangular, triangular, hexagonal, and even irregular shapes. The square, circular and rectangular are most commonly used shapes. The openings with diameter 0.25 times the web depth is considered as large opening. When beam type behavior stops to survive due to the provision of opening, then the opening may be classified as a large opening.

With the intension of determining the effect of opening, researches were done experimentally, numerically and analytically by various researchers. Bashir H. Osman et al. (2016) Conducted together the experimental and FEmethod to observe the behaviour of RC beam with opening in shear region. The main parameters considered are effective span depth ratio, opening location and size of opening. Results shows that the openings situated in a large shear area leads to the early breakdown of the beam. In addition to that, by comparing the results with those of the non linear FE analysis, it was finished in such a way that both results were in agreement. Bashir H. Osmanr et al.(2017)This paper presents a strengthening method of the Aramid Fiber Reinforced Polymers sheets that successfully strengthen RC beams. From the result it is noticeable that the break level which is existing already and the orientation of FRP have substantial effect on strengthening and mode of failure. The strength of the specimen increased and the crack width reduced compared to the control beam. Bengi Aykac et al. (2014) conducted an new investigation on RC beams among and without numerous web opening. The stirrups have a significance on the ductility of RC beam with opening, if diagonal reinforcement is not used. It is found that with the same details of reinforcement, RC beam with circular opening have superior load capacities and ductility's as compared with rectangular openings. Inorder to stay apart from Vierendeel truss action and to develop ductility and bending capacities for the beam, the posts among the openings should be prevented as per the experiment

I. ANALYTICAL INVESTIGATION

Because of the symmetry of geometry, material properties, loading, boundary conditions and also to decrease the computational expenses symmetry is being used. Fig 1.

Shows a classic finite element model with reinforcement, loading and support conditions.

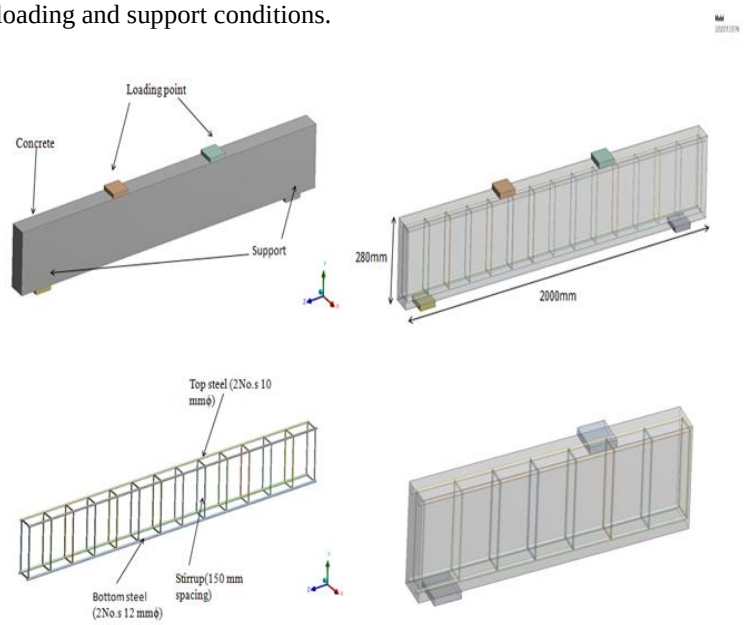

Fig 1. Reinforcement details and symmetry

A.Details of the model

An eight node element Solid65 and Link180 elements are used in the concrete and rebar's respectively. APDL commands are used to assign different element shapes to each geometry. Support and loading plates were modelled using solid 45. All the beams are tested under monotonic two point loading with simply supported condition. Load is given by an increment of 10 kN.

TABLE 1 : Details of the beams

Sl.No	Specimen	Bottom steel	Top steel	Stirrup	Opening area(mm^2)
1	Beam without opening(B1)	2ϕ12	2ϕ10	Φ8@150	-
2	Circular opening(B1C)	2ϕ12	2ϕ10	Φ8@150	13273.22
3	Elliptical opening(B1E)	2ϕ12	2ϕ10	Φ8@150	13273.22
4	Square opening(B1S)	2ϕ12	2ϕ10	Φ8@150	13273.22
5	Hexagonal opening(B1H)	2ϕ12	2ϕ10	Φ8@150	13273.22
6	Rectangular Opening(B1R)	2ϕ12	2ϕ10	Φ8@150	13273.22

II. RESULTS AND DISSCUSSION

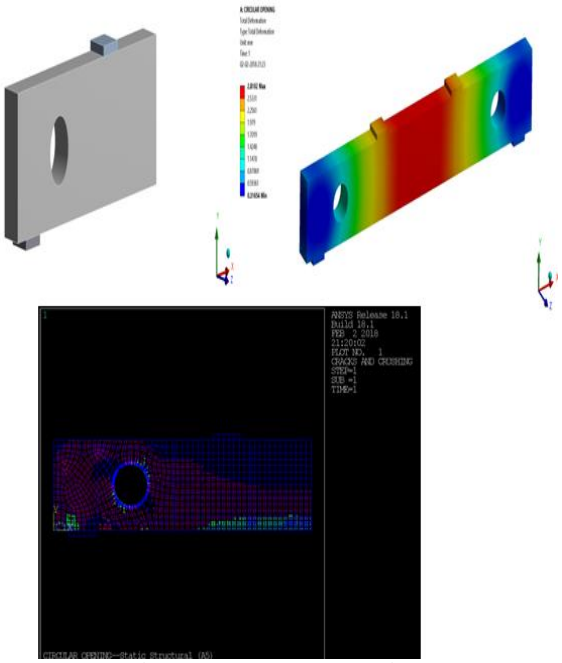

Fig 2. Geometry, deformation and crack pattern of circular opening

Maximum deformation obtained from circular opening is 2.8102mm, equivalent stress obtained is 27.495,and the ultimate load carrying capacity is 120 KN, which is 18.4% less compared to beam without opening.

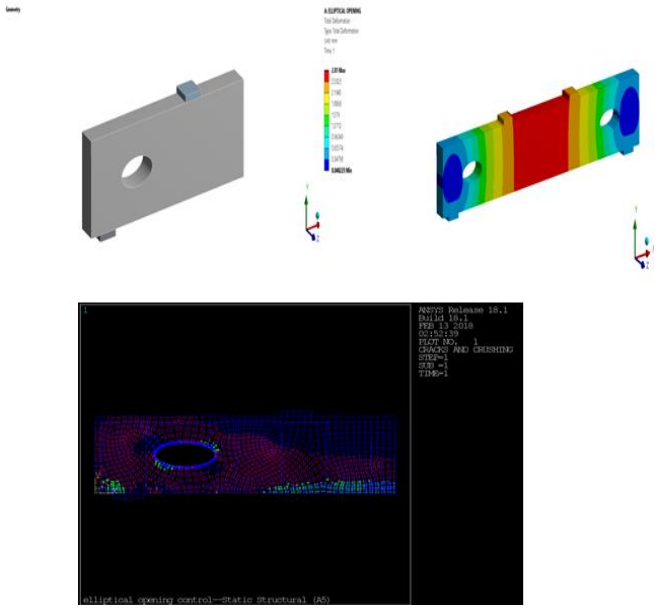

Fig 3. Geometry, deformation and crack pattern of elliptical opening

Maximum deformation obtained from elliptical opening is 2.81mm, equivalent stress obtained is 27.204,and the ultimate load carrying capacity is 119 KN, which is 19% less compared to beam without opening.

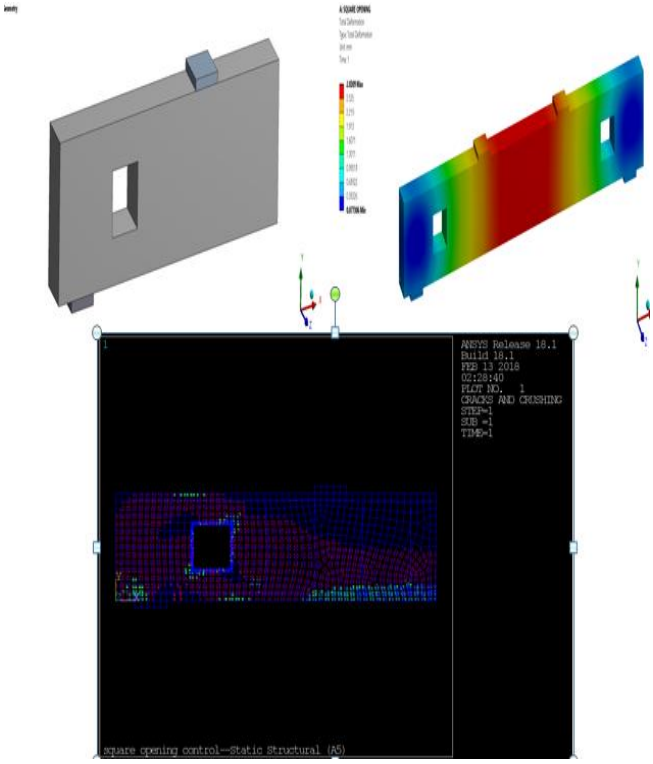

Fig 4. Geometry, deformation and crack pattern of square opening

Maximum deformation obtained from square opening is 2.8309mm, equivalent stress obtained is 27.216,and the ultimate load carrying capacity is 117 KN, which is 19% less compared to beam without opening.

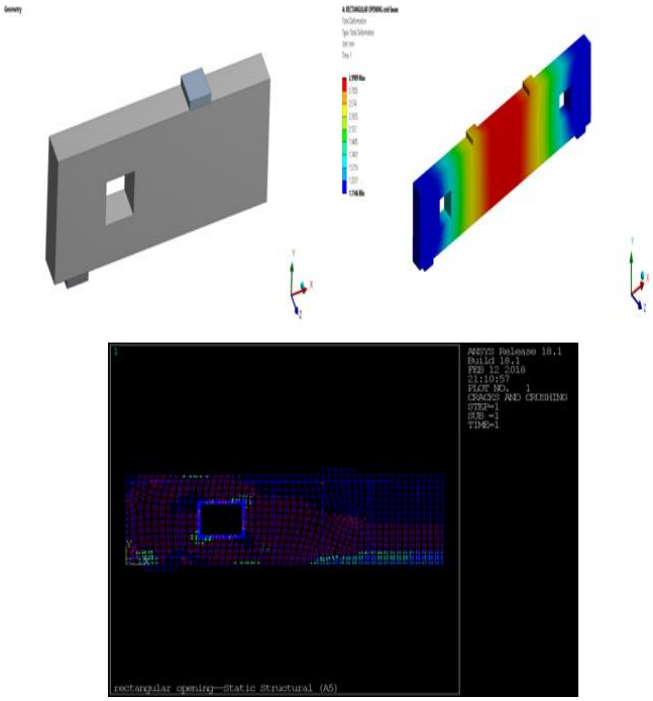

Fig 5. Geometry, deformation and crack pattern of rectangular opening

Maximum deformation obtained from rectangular opening is 2.89909mm, equivalent stress obtained is 27.055MPa, and the ultimate load carrying capacity is 115 KN, which is 21% less compared to beam without opening.

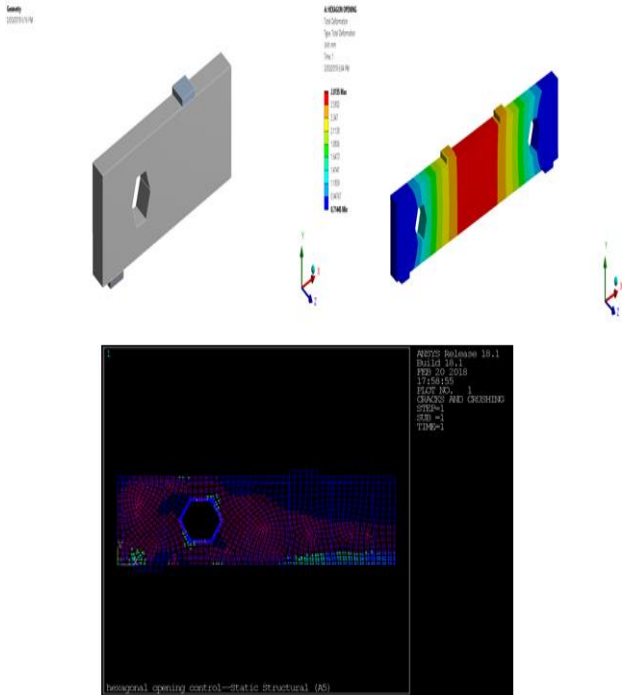

Fig 6. Geometry, deformation and crack pattern of hexagonal opening

Maximum deformation obtained from hexagonal opening is 2.8135mm, equivalent stress obtained is 27.76MPa,and the ultimate load carrying capacity is 116 KN, which is 20% less compared to beam without opening.

TABLE 2 : Results obtained from analysis

Sl.No.	Specimen	Load(kN)	Deformation(mm)
1	B1	146	2.468
2	B1C	120	2.8102
3	B1E	119	2.81
4	B1S	117	2.8309
5	B1H	116	2.8135
6	B1R	115	2.81

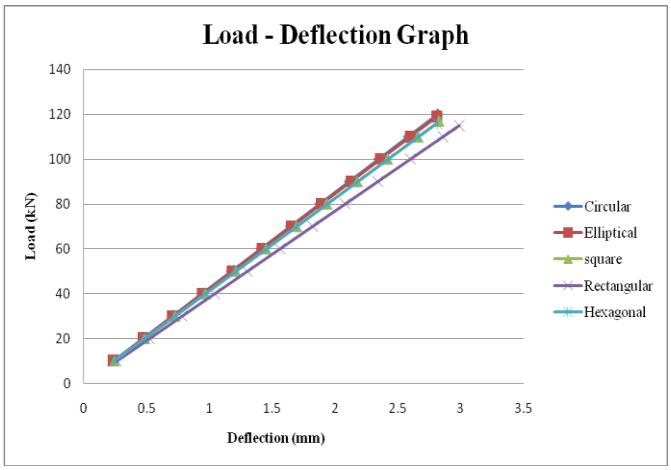

Fig 7. Combined load deflection graph for all the specimen

III. CONCLUSIONS

In this study all parameters kept constant except opening shape. From this study that the occurrence of opening in the RC beam decreases the failure load compared to the beam without opening.

- Provision of opening reduces the load carrying capacity of beam by about 17% in circular opening,19%,21%,20%, and 18.4% in square, rectangular, hexagonal, and elliptical opening respectively.
- Beam with circular opening is more better than other opening shapes. Stress concentration mainly occurs on corners. Since circular opening have no corners, stress concentrations of such openings are less
- For the entire models the first crack appeared at supports between loads 10 to 20 KN. For all the beams with opening the main cracks occur at the top and bottom chord

REFERENCES

[1] Bashir H. Osman et al.(2016)"Shear Behavior of Reinforced Concrete Beams with Circular Web Openings without Additional Shear Reinforcement",KSCE Journal of Civil Engineering, 1-11.

[2] Bashir H. Osman et al.(2017)", Repair of Pre cracked Reinforced Beams with Openings Strengthened Using FRP Sheets Under Sustained Load",International Journal of Concrete Structures and Materials,2234-1315.

[3] Bengi Aykac et al.(2014),"Flexural Behavior and Strength of Reinforced Concrete Beams with Multiple Transverse Openings",ACI structuraljournal,V. 111, No. 2.

[4] Nilesh H. Saksena et al.(2013),"Experimental Study of Reinforced Concrete Beam with Web Openings",International Journal of Advanced Engineering Research and Studies,66-68.

[5] Aykac.B et al (2013)" Flexural behavior of RC beams with regular square or circular web openings",Engineering Structures, Vol. 56, pp. 2165-2174.

[6] Campione.G et al.(2012)", Behaviour of concrete deep beams with openings and low shear span to depth ratio", Engineering Structures, Vol. 41,pp. 294-306.

[7] Md. Mashfiqul Islam, et al (2014),"Finite element analysis of SFRCvalidation of experimental shear capacities of beam", Procedia Engineering, pp:89-95.

[8] Er.Sheelu Mariam Punnoose, Er. Afia S Hameed (2016),"Shear Behavior of Reinforced Concrete Beams with CircularWeb Openings without Additional Shear Reinforcement", IJIRT, pp:1-11

[9] Er. Mareesha Susan B, Er.Ancy Mathew (2016)"Analytical study on effect of FRP wrapping in strengthening of beam with opening", IJSTE.