FINITE ELEMENT INVESTIGATION OF COLD FORM RECTANGULAR HOLLOW FLANGES STEEL BEAMS WITH OPENING IN WEBS

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Abstract - The aim of this work is the investigation and comparison of the behaviour of hollow flange steel beams and web contains openings with different location and sizes. The analytical models were used to calculate the deflection depending on the ultimate load capacity. ANSYS software was used to produce the analytical models, where ANSYS analysed hollow flange steel beams for concentrated load in the centre and constant support condition. As well as ANSYS models studied the effect of different location, number and size of square holes in web of beams models. All the beam models are is four meter length with the dimension of 400 mm beam depth, 320mm web depth, 100 mm flange width. The dimension of square opening is with 160 mm, 200mm and 240mm, which represent 0.4, 0.5 and 0.6 of the depth, respectively. The thickness of all steel section 2.5mm. The results of the models analysis showed decreasing in the ultimate load when the distance between holes decreased and the decreasing ratio as following: (4.3% to 11%) at distance ((d-a)/2) from support, (4.6% to 11%) at distance (0.25m) from support, (4.3% to 10.5%) at distance (0.5m) from support, (4% to 10.22%) at distance (0.75m) from support and (4% to 10.5%) at distance (1m) from support.

Keywords - Cold-formed steel, Hollow flanged, Non-Linear Finite Element Analysis, Square Opening Web.

I. INTRODUCTION

As well known, there are two main kinds of steel section that used in the steel structures which are hot-rolled steel sections and cold-formed steel sections. Where the cold form steel manufactures by rolling or pressing the steel into semi-finished or finished goods at relatively low temperatures (cold working) to produce the required shape. The cold formed steel was used widely in construction field in the last few decades due to its favourable properties such as the lightness and thinness, high strength and stiffness, easy manufacturing processes and the ability of controlling its quality. As well as it use in various building such as low to medium height buildings and it could applied in the high buildings by the research support from scientists and engineers.

The C-shaped and Z-shaped purlins are most unparalleled cold roll formed section which are used for fixing the roof panels and to transfer the roof wind and snow members. There are many benefits for using C purlins such as unrestrained thickness and depth options and that give more freedom for designer that required to design the most economical purlin. Steel beams with holes web are beautiful, versatility and economical in steel design. In modern building, the openings are required to provide the structural members so as to the services of the building could be combined into structural zones for facilitation of planning and installation. General depth of the construction zone may be reduced as a result of link the building services to the construction zone, and this useful buildings with multi-story and large headroom requirement.

Pi and Trahair (1997) presented an evidence for using hollow flanged steel sections and explained the lateral-distortional buckling for hollow flange beams. Where they study the flanges and webs of cold formed hollow flange beams (HFBs). Also they found that the flange of these beams are stiff torsional while the webs are flexible, so it reduce the resistances to lateral buckling.

Later on Avery et. al. (1999) develop Pi and Trahair (1997) idea by putting web stiffeners with the section and studied the flexural capacity of the section. And in order to have a best imaginary about the action of the supposed hollow flanged section Wilkinson and Hancock (1999) studied the finite element analysis of plastic bending of cold formed rectangular hollow section (RHS) beams. The main objectives of this analysis were to decide trends, to comprehend the occurrence of inelasticity of instability, and to try to predict the rotation capacity of cold-formed RHS beams.

Wanniarachchi (2005) try to find alternative section for rectangular section by using triangular hollow flange and assessed the flexural behaviour of these kinds of sections by using riveted profile hollow flanged beam to rectangular connections. Later or Zhao (2005) developed the idea of research by using some techniques to take both kind of cold forming connections, namely, self-piercing riveting and arc-spot welding. After that, Mahendran (2007) use of the finite element methods extensively in investigating fully the structural performance of a number of building components and systems. In 2008 Vieira et.al., developed the structural behaviour of a cold-formed steel purlin sheeting system by using calculation methods, considering material and geometrical nonlinearity, and moreover the effect of contact between the purlin, sheeting, and connection.

Snow (2008) study the connection between arc spot weld shear strength and the arc time utilized to form the weld. Lap shear examinations were performed on

both 3/4 in. and 5/8 in. 6 diameter welds. The data was taken from the strength tests and the sectioning samples to prove that welds formed using reduced arc times were significantly smaller and weaker than fulltime welds. Karunakaran and Santhi (2013) used variable hollow flange depths when studied the1. behaviour of rectangular hollow flanged Z beam (RHFZB) sections and reached that the section with2. dimension (120x50x30x1)mm showed better behaviour in terms of capacity and ease of fabrication. This research studied the behaviour of beams which contains voids (square opening) in different position, number ,and size (160 mm, 200mm and 240mm) by using ANSYS finite element program.

II. MODELLING AND ANALYSIS OF C SECTIONS

The dimension of the section that studied is shown in Figure (1) which shows all dimensions in mm and the square holes dimensions are a= 160 mm, 200 mm and 240 mm, which change to study the effect of holes dimensions, number and location on the behaviour of the beam. While the beam material and properties are shown in Table 1.

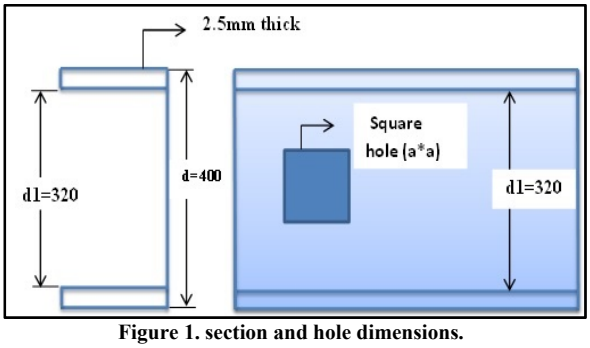


Figure 1. section and hole dimensions.

Material type	Element type	Material properties	
Steel	SOLID 45	Linear Isotropic	
		EX	200000
		PRXY	0.3
		Bilinear Isotropic	
		Yield stress	300
		Tang mod	2000

Table 1. beams materials and properties.

ANSYS software was used to produce modelling analysis for hollow flanged C- sections without and with square holes. Figure (2) shows the modelling of C sections without hole and Figure (3) shows the modelling of C sections with different voids number and location in the web. And the accuracy of the values/result based on the pattern of each beam sample. The C-sections are tested analytically with concentrated load in the centre. Where the beam sections are loaded incrementally to study the deformation characteristics during the loading process.

To analyze the lateral distortional buckling behaviour of the C sections hollow flanged beam with and without holes, two substitutes were available:

Elastic buckling examination to find the critical buckling load and buckled shape.

Non-linear static analysis which including both geometric and material non-linearity in order to identify the complete load-displacement behaviour, with lateral-buckling.

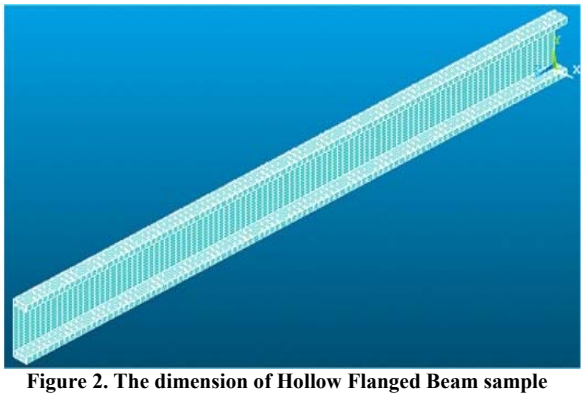


Figure 2. The dimension of Hollow Flanged Beam sample (400*100*40*2.5) in ANSYS.

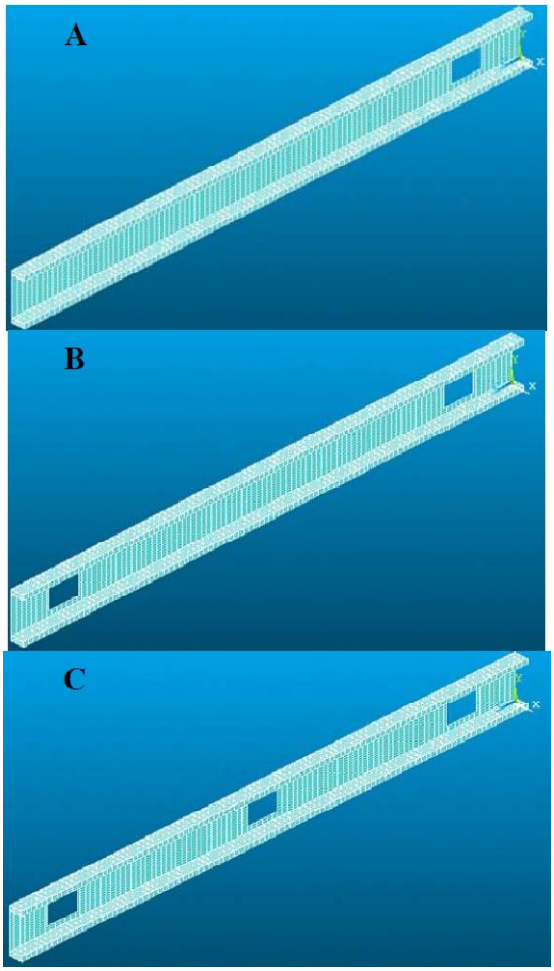


Figure 3. Hollow Flanged Beam (400*100*40*2.5) with different void numbers and locations in the web, A) one space, B) Two spaces & C) Three spaces.

III. RESULTS OF ANSYS MODELS

The results that have been obtained from ANSYS-14 which used to study the change in buckling load. And results of the analysis are presented in Table (2).

Sample ID		Hole Position						
		-	(d-a)/2	(0.25) m	(0.5) m	(0.75) m	(1) m	(2) m (Centre)
		Load (kN)						
Without hole		67.5	-	-	-	-	-	
One hole	0.4d	-	67.095	66.996	67.102	67.162	67.2	65.433
	0.5d	-	66.7	66.7	66.8	66.9	66.9	63.7
	0.6d	-	66.4	66.1	66.3	66.6	65.4	62.082
Two holes	0.4d	-	66.7	64.8	66.6	66.7	66.8	-
	0.5d	-	65.965	65.9	66.1	66.3	66.278	-
	0.6d	-	65.3	64.8	65.3	65.6	65.4	-
Three holes	0.4d	-	64.6	64.4	64.6	64.8	64.8	-
	0.5d	-	62.3	62.255	62.5	62.6	62.6	-
	0.6d	-	60.1	59.947	60.4	60.6	60.4	

Table 2. Parametric characteristics of finite element for

The lateral-distortional buckling loads are obtained from the finite element programme and shown in the following figures. Figures (4 to 13) shows the load-lateral deflection curves for beams with different holes numbers and dimensions. The axial compressive load to axial displacement curves for the C- section hollow flange with opening web shown in Figures (from 14 to 23) from the results of the curves the following could be demonstrated, the increasing in the hole depth was lead to decreasing the ultimate load capacity about (0.44% to 3.1%) for one hole, (1% to 4%) for two holes, (4% to 11%) for three holes as shown in Figure (20). On the other hand the increasing of holes number in web of beam will decrease the ultimate load capacity about (10% to 11%) for all distances. The location of the holes has an effect on the ultimate load. Ultimate load is decreased about (1)% for one hole, (1.2 to 3.26)% for two holes and (4.3 to 11)% for three holes at distance ((d-a)/2) from support. Also, (0.7 to 2)% for one hole, (2.4 to 4)% for two holes and (4.6 to 11)% for three holes at distance (0.25m) from support. While, (0.6 to1.7)% for one hole, (1.3 to 3.2)% for two holes and (4.3 to 10.5)% for three holes at distance (0.5m) from support. Also, (0.5 to1.3)% for one hole, (1.18 to 2.8)% for two holes and (4 to 10.2)% for three holes at distance (0.75m) from support and (0.44 to 3.1)% for one hole, (1 to 3.11)% for two holes and (4 to 10.5) % for three holes at distance (1m) from support. Thus, When the hole located at the beam centre, it will subject to concentrated load at mid span and the ultimate load will be decreasing from(3.1% to 8%).

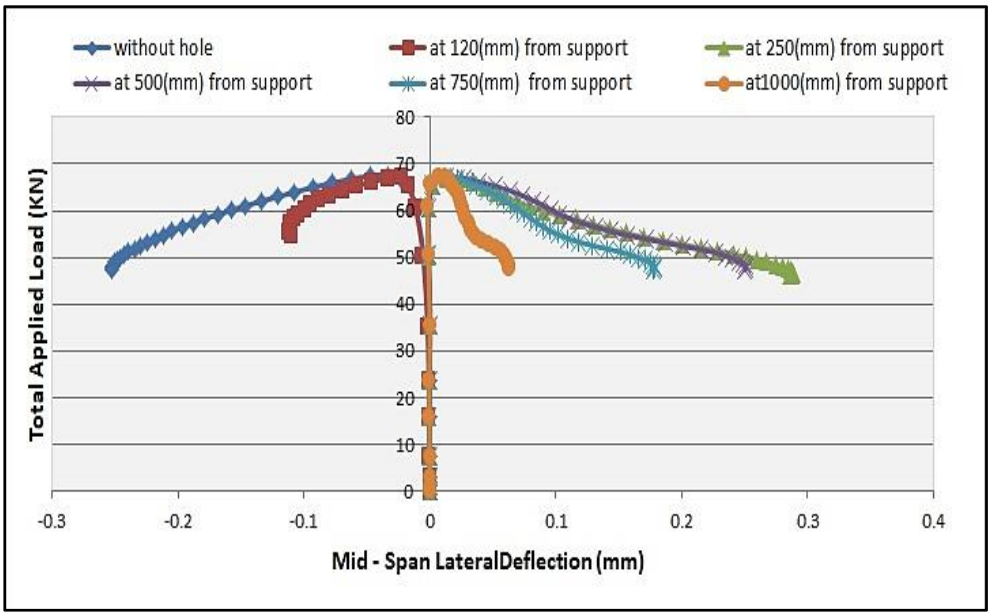


Figure 7. Load-Lateral deflection for beams with one hole (0.4*d)

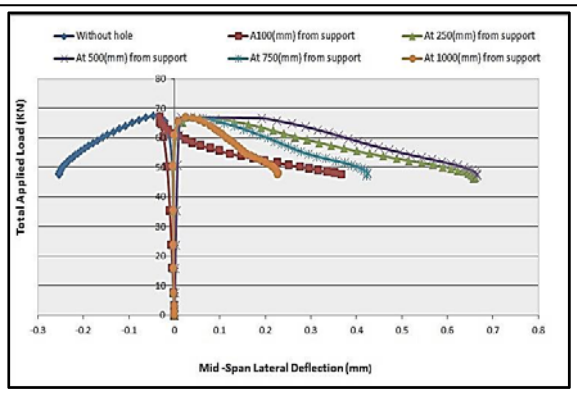


Figure 8. Load-Lateral deflection for beams with one hole (0.5*d)

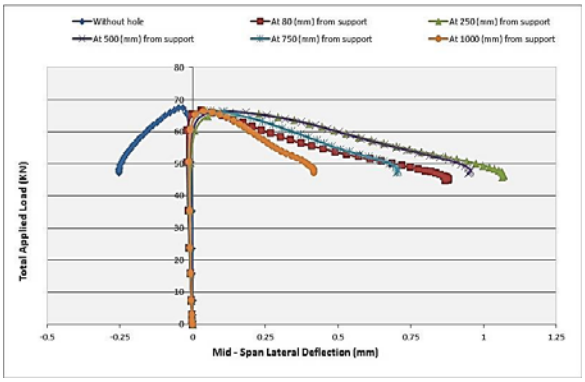


Figure 9. Load-Lateral deflection for beams with one hole (0.6*d)

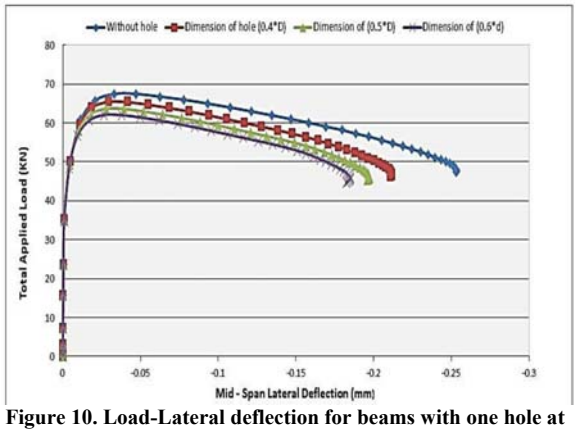


Figure 10. Load-Lateral deflection for beams with one hole at centre

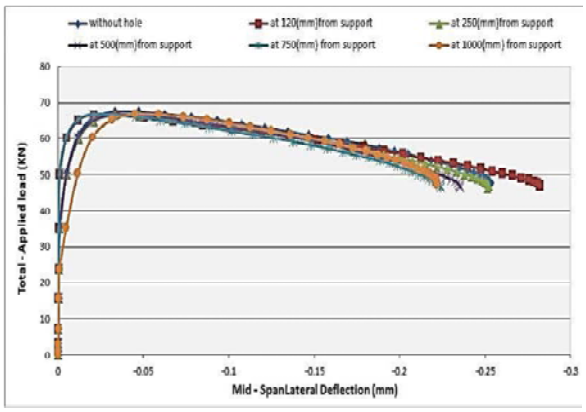


Figure 11. Load-Lateral deflection for beams with two holes (0.4*d)

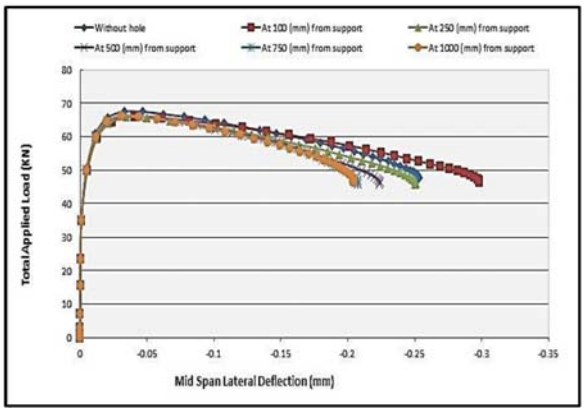


Figure 12. Load-Lateral deflection for beams with one hole (0.5*d)

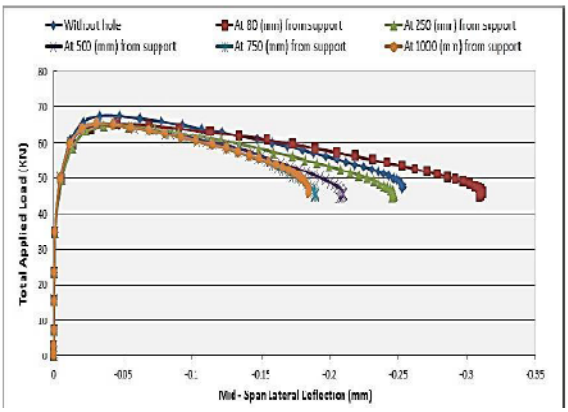


Figure 13. Load-Lateral deflection for beams with two holes (0.6*d).

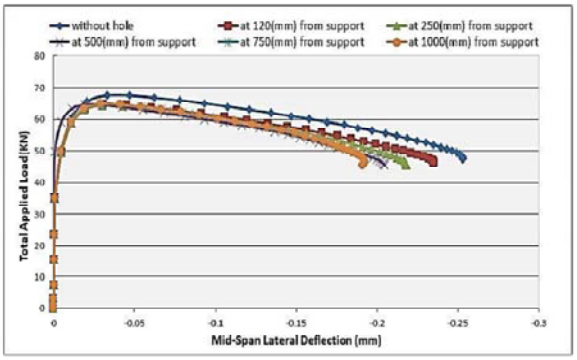


Figure 14. Load-Lateral deflection for beams with three holes (0.4*d)

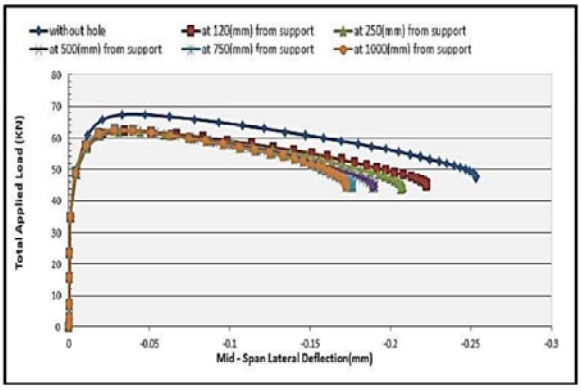


Figure 15. Load-Lateral deflection for beams with three holes (0.5*d).

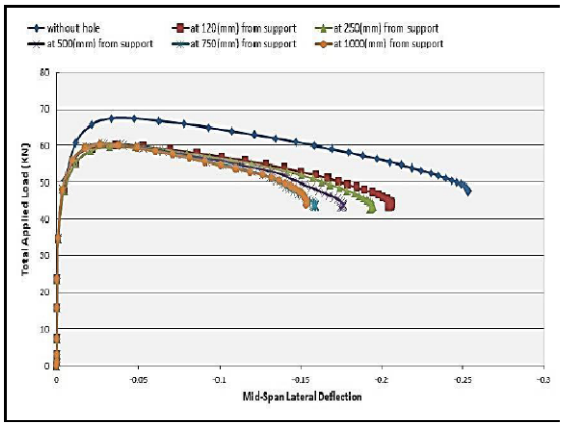


Figure 16. Load-Lateral deflection for beams with three holes (0.6*d).

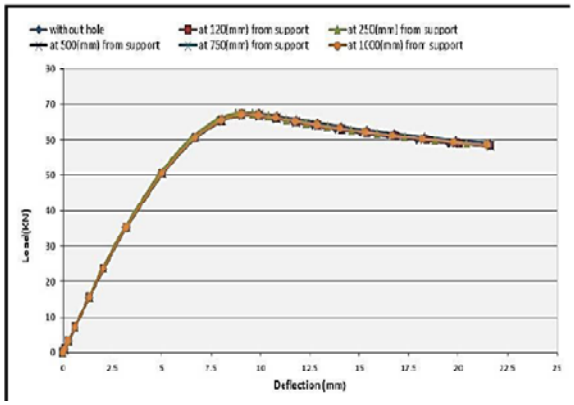


Figure 17. Load-Deflection for beams with one hole (0.4*d).

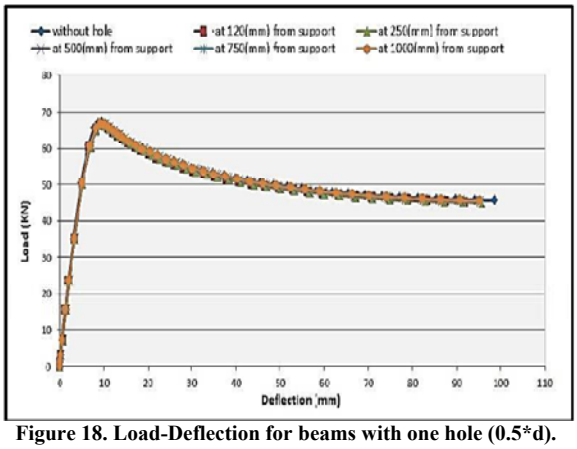


Figure 18. Load-Deflection for beams with one hole (0.5*d).

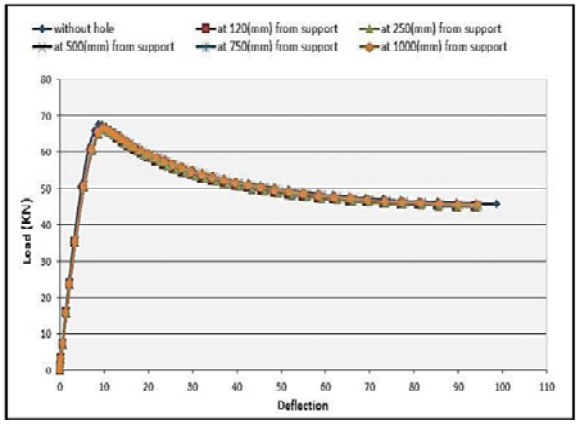


Figure 19. Load-Deflection for beams with one hole (0.6*d).

IV. CONCLUSION

The analysis of C- section hollow flange steel beams with web openings for deflection and ultimate load capacity is done by ANSYS software. The following conclusion can be obtained:

1. The beam without holes in web has less deflection in comparison with beam with holes in web.
2. The increasing the depth or the number of holes lead to increase the mid-span deflection in the beam under the same load capacity.
3. The distances between the holes has an important effect on the ultimate load. The increase in the distance between the holes will increase the ultimate load.
4. The load-lateral deflection curves effected by both the numbers of the voids and the size of the void, so increasing the number of voids was increasing the deflection due to lateral load. On the other hand, the best condition for load-lateral deflection curves had been recorded when the beam has one void located at the middle of mid span and the void dimension (0.5*d).
5. The ductility of beam was when the holes position are between support and in the beam centre.

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