Moment and Shear Analysis of Beam with Different Web Openings

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ABSTRACT

Vierendeel mechanism is always critical in steel beams with single large web openings. While depth of web openings controls both the shear and the flexural failures of the perforated sections, it is the length of the web openings that governs the vierendeel mechanism which in turn depends on the shear and moment capacities of the tee sections above and below the web opening.

In this paper Finite element Analysis is done by using Ansys for given beam in previous literature of K.F. Chung (1) and the result of shear force and bending moment are compared.

Then same formula are used to solve the beam with two web opening instead of six opening and comparison is done between the theoretical values and the analysis by finite element method.

Subsequently the shear force and bending moment is obtained by finite element analysis using Ansys for different depth of opening to depth of beam ratio and three different types of web opening shapes such as hexagonal, rectangular and circular.

Keywords –**Castellated beam, Cellular beam, Finite element analysis,Vierendeel mechanism**

I. INTRODUCTION

Modern multistoried buildings always have a stringent requirement on headroom. In order to accommodate building services within the constructional depth of a floor, it is common practice to provide web openings in structural floor beams for passage of services such as air-conditioning pipeline, cables and ducts. A large amount of research efforts on the structural behavior of steel beam with web opening have been reported in the literature, primarily for steel beam with multiple hexagonal web opening. In a perforated section under a moment and shear force three actions are induced in the tee-sections above and below the web opening 1) Axial force 2) Shear force 3) Moment in the tee section. For beam with given loading and support condition, the magnitude of the action depends on the shapes, the sizes and also the location of the openings. An overall review on the design recommendations shows that in general, there are two design approaches in assessing the structural behavior of steel beams with web openings. 1) Tee section approach 2) Perforated section approach

In the present investigation, all steel beams are hot rolled steel I sections. All web opening are concentric to the mid – height of the sections with depth between 0.5 to 0.8D where D is the overall depth of section. No reinforcement is considered around the openings. Both the bending moment and the shear force are evaluated at the center of the web opening.

II. CALCULATION OF SHEAR FORCE AND BENDING MOMENT:

(A) WORKED EXAMPLE BY K.F. Chung (1)

A 7.5-m span simply supported beam of UB457 × 152 × 52 S275with six Hexagonal web openings (do = 0.75 h) is subject to a uniformly distributed load of 35 kN/m. The openings are placed symmetrically about the center of the beam with an interval of 1.0 m starting from the supports. Check the structural adequacy of the steel beam

Data

L=7.5 m; Xo=1.0, 2.0, 3.0 m; h=depth of beam= 449.8mm; tw=thickness of web= 7.6 mm; bf=flange width= 152.4 mm; tf= thickness of flenge=10.9 mm; do=depth of opening= 337.35 mm; Wpl=1096 × 103 mm^3.

Steel beams with C-hexagonal web openings as shown in Fig1 and result of Theoretical calculation in Table1.

ANSYS GEOMETRY MODEL

ANSYS model is prepared as shown in Fig 2 for the problem (A) and analyzed for shear force and moment result at different locations.

(B) ANOTHER EXAMPLE: A 4-m span simply supported beam of ISMB 300 with two Hexagonal web openings (d = 0.5 D) Depth of Hole/Depth of beam = d/D= 0.5 is subject to a pressure Loading of 100 kN/m^2 having α=45° The openings are placed symmetrically starting from the supports. *Find Shear and Moment at the center of Hexagon i e at 1000 mm from the edge of bea*m

Theoretical Solution of shear force and moment at center of the web opening is tabulated in Table 2

ANSYS GEOMETRY MODEL

ANSYS model is prepared as shown in Fig 3 for the problem (B) to compare theoretical and ANSYS results for shear force and moment at the center of the opening

The comparison of theoretical and Ansys Result for the above problems (A) and (B) is shown in Table 3

III. PROBLEM STATEMENT:

TO CALCULATE THE SHEAR FORCE AND MOMENT FOR THREE DIFFERENT SHAPES AND SIZES OF WEB OPENING

Example: A 4-m span simply supported beam of ISMB 300 with two web openings for different Depth of Hole/Depth of beam = d/D ratio is subject to a pressure Loading of 100 kN/m^2 having α=45° in case of hexagonal opening. The openings are placed symmetrically starting from the supports. *Find Shear and Moment at the center of opening i e at 1000 mm from the edge of bea*m.

Case 1: Castellated Beam (hexagonal opening) as shown in Fig 4

Case 2: Rectangular opening as shown in Fig 5

Case 3: Cellular Beam (circular opening) as shown in Fig 6

Result of shear force and moment at the center of the opening for different d/D ratio such as d/D=0.5,0.6,0.7,0.75and 0.8 in three different shapes of web opening condition is tabulated in the Table 4 as shown below:

Table 1:
Theoretical shear force and bending moment values for problem (A)

x_0 (m)	d_0/h	w (kN/m)	$\bar{v}$	V_{Sd} (kN)	v	M_{Sd} (kNm)	$M_{o,Rd,Vi}$ (kNm)	$\frac{M_{Sd}}{M_{o,Rd,Vi}}$	Checking
1	0.75	35	0.91	96.3	0.587	113.8	195.9	0.581	OK
2	0.75	35	0.91	61.3	0.374	192.5	224.4	0.858	OK
3	0.75	35	0.91	26.3	0.160	236.3	238.8	0.989	OK

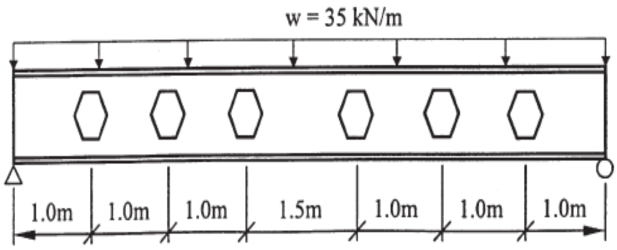

figure 1: Diagram for problem (A)

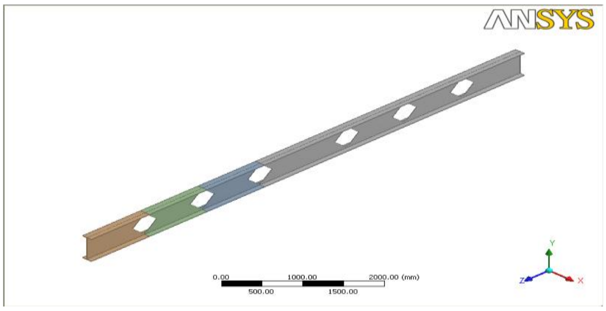

figure 2: Ansys model for problem (A)

Table 2
Theoretical shear force and bending moment values for problem (B)

Xo (m	$Vsd = W\left(\frac{L}{2} - Xo\right)\ (kN)$	V	$Msd = \frac{WXo(L - Xo)}{2}(kNm)$
1m	14*(4/2-1)=14 kN	Vsd/ Vrd = 6.676E-11	14*1*0.5*(4-1) = 20.985

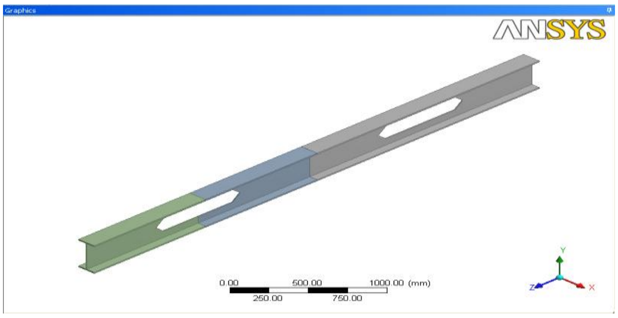

figure 3: Ansys model for problem (B)

Table 3:
Comparison of Theoretical and Ansys result of Shear force & Moment for problem (A) & (B)

Location	Theoretical Result	ANSYS Results	Variation in mm
Shear force at 1m from support	96.3	96.3	Nil
Shear force at 2m from support	61.3	61.3	Nil
Shear force at 3m from support	26.3	26.3	Nil
Moment at 1m from support	195.9	195.9	Nil
Moment at 2m from support	224.5	224.5	Nil
Moment at 3m from support	238.8	238.8	Nil
Shear And Moment at 1m obtained for problem (B)			
Shear force at 1m from support	14	14	Nil
Moment at 1m from support	20.98	20.98	Nil

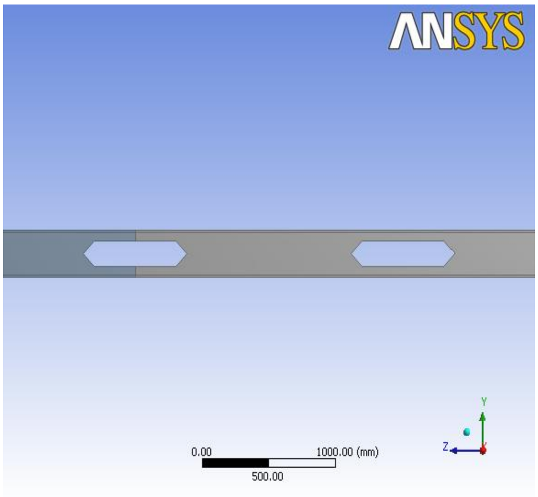

figure 4: Model of Castellated Beam for case 1

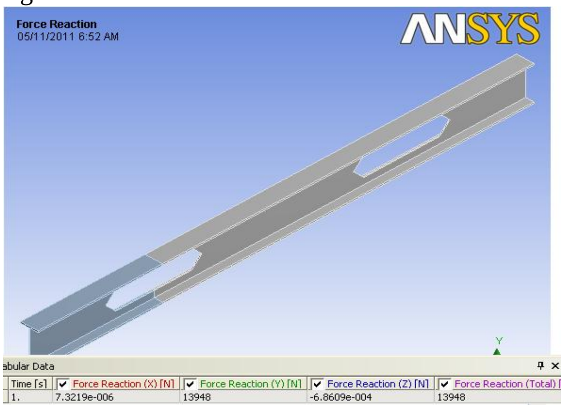

figure 4a: Ansys shear force values for d/D = 0.6 in case 1

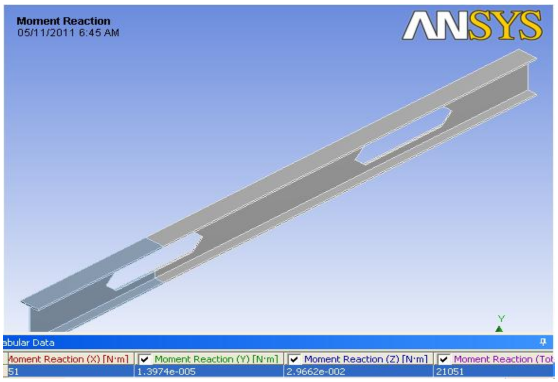

figure 4b:Ansys bending moment values for d/D = 0.6 in case 1

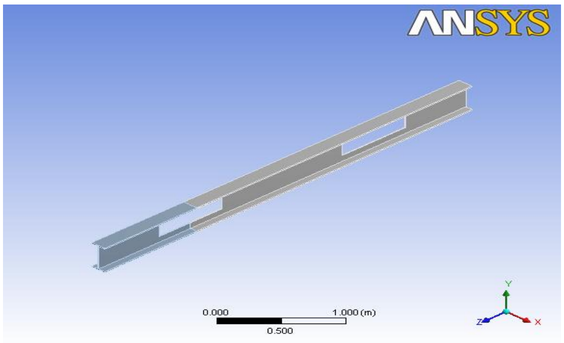

figure 5: Model of Rectangular web opening for case 2

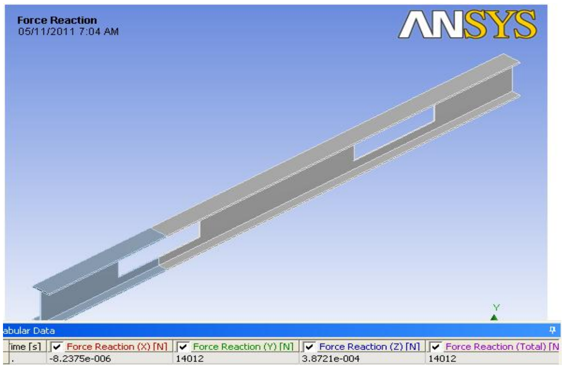

figure 5a: Ansys shear force values for d/D = 0.5 in case 2

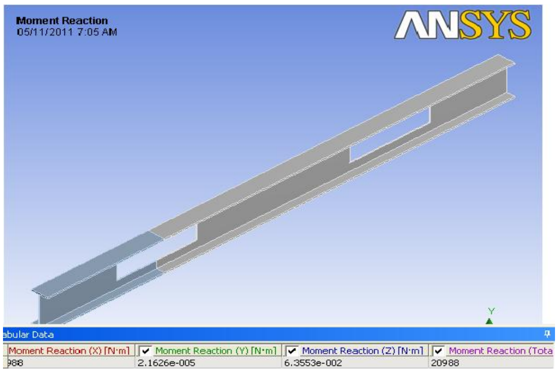

figure 5b: Ansys bending moment values for d/D = 0.5 in case 2

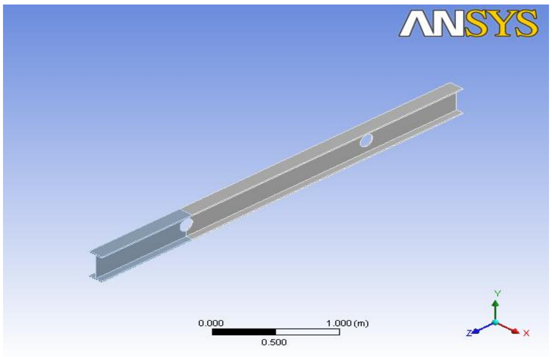

figure 6: Model of circular beam for case 3

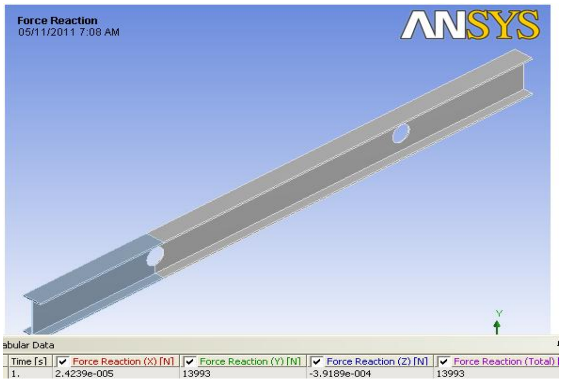

figure 6a: Ansys shear force values for d/D = 0.5 in case 3

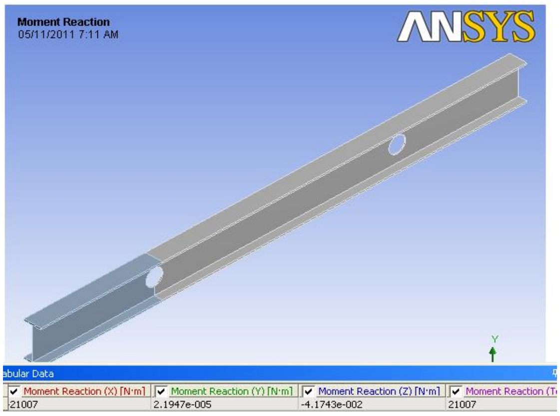

figure 6b: Ansys bending moment values for d/D = 0.5 in case 3

Table 4:
Comparison of shear force and bending moment values of different d/D ratio for case1, case2 & case3

Location	Hexagon	Rectangular	Circle
Shear Force result at the center of opening			
Shear force at 1m from support for d/D = 0.5	13.997	14.012	13.993
Shear force at 1m from support for d/D = 0.6	13.948	14.05	13.978
Shear force at 1m from support for d/D = 0.7	13.882	14.13	13.974
Shear force at 1m from support for d/D= 0.75	13.882	14.039	13.978
Shear force at 1m from support for d/D = 0.8	13.123	14.048	13.978
Bending Moment Results at the center of opening			
Moment at 1m from support for d/D = 0.5	21.003	20.988	21.007
Moment at 1m from support for d/D = 0.6	21.051	20.969	21.022
Moment at 1m from support for d/D = 0.7	21.117	20.966	21.021
Moment at 1m from support for d/D = 0.75	21.117	20.963	21.022
Moment at 1m from support for d/D = 0.8	21.849	20.952	21.022

IV. Result And Conclusion

1) There is no variation observed in theoretical values and finite element analysis results obtained by Ansys.
2) Formula of the K.F. Chung (1) research Paper can be easily used for different number of web opening for same boundary condition and loading condition.
3) Shear force is more in rectangular opening as compare to Hexagonal and circular web opening
4) Bending moment is less in rectangular opening as compare to Hexagonal and circular web opening
5) In case of circular opening shear force as well as moment capacity is almost equal for all d/D ratios.
6) The shear force reduces as d/D ratio increases whereas bending moment increases.

V. References

Journal Papers

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