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Study Behaviour of Castellated Beam with Diagonal Stiffeners within and Outside the Opening by Using ABAQUS Software

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Abstract- castellated beams are generally made of hot rolled profiles by flame cutting of the parent profile & those beams have a growing use in steel construction as they have a good strength to weight ratio. After that, they provide the possibility to pass through the web openings various kind of services which reduces the floors depth and lead to an optimal use of space and steel material. Castellated beam in comparison with standard beams, those with web openings show specific behaviors and failure modes which led to various experimental and numerical studies. Nowadays, many analytical models have been developed to evaluate the resistance of the beams with web openings. Then, the finite element code, ABAQUS, is developed to perform elastic buckling analysis and predict critical loads for all tested specimens. Three-dimensional nonlinear finite element analysis results of these steel cellular beams are then compared with the experimental results.

I. INTRODUCTION

The work in dissertation is mainly focused on the stiffeners provided for the perforated beam also known as castellated beam or cellular beam as per the shapes provided for beam.

I-beams subjected to flexure have much greater strength and stiffness in the plane in which the loads are applied (major axis) than in the plane of the minor axis. Unless these members are properly braced against lateral deflection and twisting, they are subjected to failure by lateral–torsional buckling prior to the attainment of their full in-plane capacity. Lateral–torsional buckling is a limit state of structural usefulness where the deformation of a beam changes from predominantly in-plane deflection to a combination of lateral deflection and twisting while the load capacity remains at first constant, before dropping off due to large deflection and yielding. Castellated beams are made by either flame cutting or automatically cutting a rolled beam's web in a zigzag pattern along its centerline and then rejoining the two halves by welding. This opening up of the original rolled beam increases its section modulus of inertia about its major axis and results in greater vertical bending strength and stiffness without any change in weight. The presence of large web openings may have a severe penalty on the load carrying capacities of castellated beams, depending on the shapes, the sizes, and the location of the openings.

Stiffness requirements of central lateral restraints that are intended to restrain inelastic simply supported castellated beams so as to increase their lateral buckling moment to those of rigidly restrained beams under pure bending. For this purpose, a finite-element model is developed for the nonlinear inelastic flexural–torsional analysis of castellated beams with a wide variety of slenderness and brace stiffness. Then, it is used to investigate the effect of elastic lateral bracing stiffness on the inelastic flexural–torsional buckling load of simply supported castellated beam with an elastic lateral restraint under pure bending.

II. ANALYSIS OF CASTELLATED BEAM

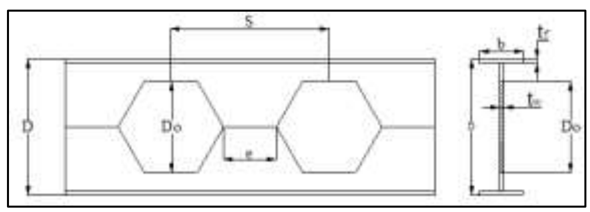

Figure No. 1: Typical Cross Section Of The Beam

Table No 1: Dimensions of Castellation Beam

Original Section Length	Length of Side of Hexagonal	Depth of opening provided	Overall depth of the opening	Width of flange of I beam	Thickness of flange of I beam	Thickness of web of I beam
	a	D_0	D	b	t_f	t_w
150	86.6	150	225	50	5	5

Table No 2: Check For Moment (Flexural) Capacity Of The Beam

Area of upper or lower Tee	Yield stress of steel	Lever arm	Moment capacity of the upper or lower Tee
A_{tee}	P_y	z	M_{pTee}
$((D-D_o)*0.5)*t_w+b*t_f$		D/2	$A_{Tee}\times$ Py × z
437.5	250	112.5	12304687.5

Table No 3: Check For Shear Capacity Of The Beam

Shear area (shear area of whole cross section)	Shear strength of castellated beam	Shear area of Tee	Vertical shear capacity.	Horizontal shear area	Horizontal shear capacity
Av	P_v	A_{wt}	P_{vy}	A_{mwt}	P_{vh}
(D-2tf)×tw	0.6×Py×Av	(D-2tf-Do)×tw	0.6×0.9×Awt	e × tw	0.6×Py×Amwt
1075	161250	325	175.5	300	45000

Table No 4: Check For Flexural And Buckling Strength Of Web Post

Horizontal Shear Capacity	Bending Moment Of Critical Web Post Section	Bending Resistance Of Critical Web Post Section
P_{vh}	M_{max}	M_e
	$P_{vh}\times(Do/2)$	$(t_w\times P_y\times(S-2b)$^2)/2
45000	3375000	7562500

III. ABAQUS MODELLING

In this section, the modelling of castellated beam in ABAQUS is explained in brief. Following are the points which involves in FEA in ABAQUS.

A. Preparing a Part Model:

The pictorial view of part model of castellated beam along with loading and boundary conditions is shown in Fig.1

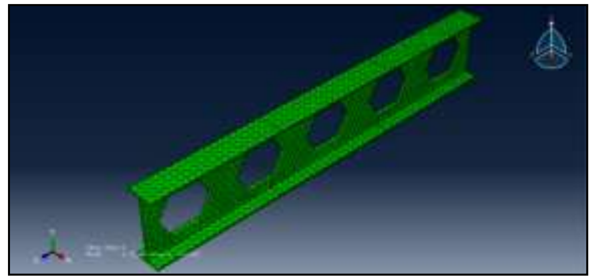

Figure No.2: Part Model Of Castellated Beam Without Stiffener Along With Loading And Boundary Conditions

B. Material Properties and Section Assignment

After creating part model, in the next property module create a material by putting elastic property such as Young's modulus (2 x 105 N/mm2) and Poisson's ratio (0.3) of steel.

C. Assembly of Model

It is important to do the assembly of the model in caste of complicated structure. In assembly module create instance by selecting dependent type.

D. Selection of Type Analysis

In next step module create step to fix analysis as static general which will perform bending analysis of structure.

E. Loading and Boundary Condition

In load module concentrated load by selecting point of loading and apply boundary conditions by selecting proper edges. Simply supported condition is taken in consideration.

F. Meshing of model

Meshing is the most important parameter in FEM in ABAQUS, it is very important to select proper mesh size and type of element to get accurate results. In case of castellated beam select the Quad-dominated structured element. Which is S4R doubly curved shell element, which will give accurate results in case of castellated beam with circular perforations.

G. Submission for analysis and visualization of results

After meshing has been done, now model is ready for analysis. This is done in job module by creating job and submitting it.

After analysis is completed we can see the results in visualization module. In visualization various types of results are generated from which von-misses stresses and deflection in Y-direction are of our concern, this can be found out in dropdown menu of results as S-Misses and U2 respectively.

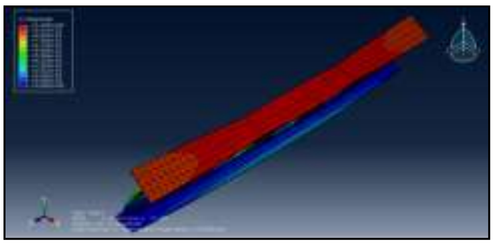

Figure No 3: Sample Results Of Eigen Value Of Castellated Beam Using Diagonal Stiffener

IV. VALIDATION OF SOFTWARE

In recent years, little research work has been published on the design of castellated beam and particularly for castellated beams with hexagonal openings. ISMB 150 and ISMB 200 are selected for fabricating castellated beams. The castellated beams were fabricated such that depth of the beam is 1.5 times the original depth as IC 225 and IC 300 respectively with an angle of cut 45°.

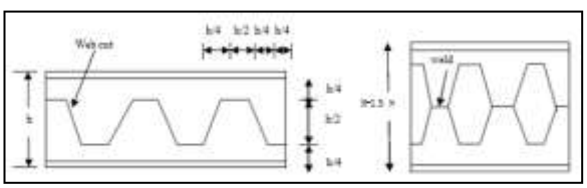

Figure No.4 Sample Considered For The Validation

Select the depth of the stem of the T section at the minimum cross section should not be less than ¼ of the original beam section.

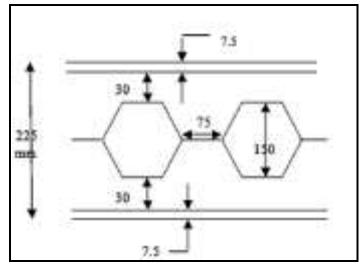

Figure No 5: Sample Considered For The Validation With WVS 225

Fig. 5 explains marking layout of I section ISMB 150 shows the castellated beam with an increased depth (225 mm from 150 mm) as IC 225.

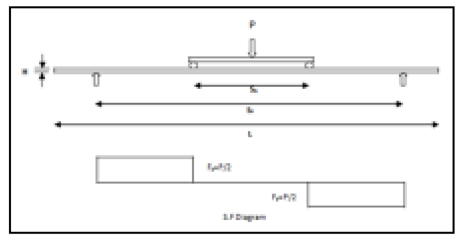

Figure No 6: Loading considered for WVS 225

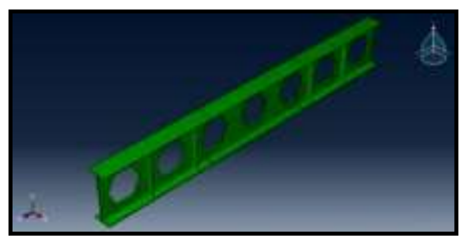

Figure No 7: Result For Load Carrying Capacity Of Model In Research Paper

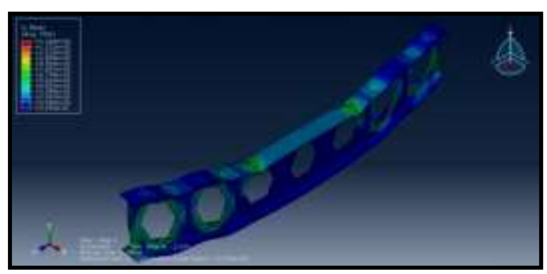

Figure No.8: Result For Deflection Of Model In Research Paper

Table No. 5: Result for load carrying capacity of model in research paper

Sr. No	Load	WVS 225 Deflection		Percentage Error
		B. Anupriya et al.	ABACUS	
1	10	1.6	1.41	11.80
2	20	3.17	2.70	14.87
3	30	4.77	4.23	11.27
4	40	6.35	5.64	11.20
5	50	7.94	7.05	11.16
6	60	9.52	8.47	11.08
7	70	11.12	9.88	11.19
8	80	12.72	11.29	11.26
9	90	14.29	13.55	5.21
10	100	15.89	14.11	11.19

V. RESULTS

A. Load Carring Capacity of Diagonal Stiffener within Opening

The parameters considered for the diagonal stiffeners are thickness and width of the stiffener. For diagonal stiffener the thickness is 5mm and then according to Euro code the minimum provision of area As=30Ɛtw where maximum area criteria for diagonal stiffener is considered to be equal of undisturbed strip area, which is 30% of the area of hollow opening. Hence, the according to it thickness x width combinations are made. Spacing for diagonal stiffeners is equal to S i.e. for hexagonal beam spacing = 225. All the stiffener sizes provided for the castellated beams are given in Table. These all diagonal stiffeners are modeled and analyzed in ABAQUS software and optimized section is found out.

Table No.6: Load Carring Capacity of Diagonal Stiffener within Opening

Sr No	Thickness	width	Total Volume For 5	Load Carring Capacity	Ratio
1	5	10	72500	108.61	1.50
2		11	79750	108.195	1.36
3		12	87000	109.07	1.25
4		13	94250	108.63	1.15
5		14	101500	109.2	1.08
6		15	108750	112.378	1.03
7		16	116000	113.163	0.98
8		17	123250	114.716	0.93
9		18	130500	114.836	0.88
10		19	137750	113.694	0.83
11		20	145000	113.678	0.78

B. Load Carring Capacity of Both Side Diagonal Stiffeners Throughout

The parameters considered for the diagonal stiffeners are thickness and width of the stiffener. For diagonal stiffener the thickness is 5mm, 6mm, 8mm, 10mm, 12mm and 16mm then according to Euro code the minimum provision of area As=30Ɛ tw where maximum area criteria for diagonal stiffener is considered to be equal of undisturbed strip area, which is 30% of the area of hollow opening. Hence, the according to it thickness x width combinations are made. Spacing for diagonal stiffeners is equal to S i.e. for hexagonal beam spacing = 225. All the stiffener sizes provided for the castellated beams are given in Table. These all diagonal stiffeners are modeled and analyzed in ABAQUS software and optimized section is found out.

Table No.7: Load Carring Capacity of Both Side Diagonal Stiffeners Throughout

Sr. No	Thickness	Width	Total Volume For 5	Load Carring Capacity	Ratio
1	5	10	150270	155.365	1.03
2		11	165297	159.544	0.97
3		12	180324	154.690	0.91
4		13	195351	168.753	0.86
5		14	210378	172.755	0.82
6		15	225405	177.034	0.79
7		16	240432	181.962	0.76
8	6	10	180324	172.443	0.96
9		11	198356.4	178.08	0.90
10		12	216388.8	184.216	0.85
11		13	234421.2	189.296	0.81
12	8	10	240432	212.885	0.89
13	10	5	150270	192.564	1.28
14		6	180324	206.996	1.15
15		7	210378	221.275	1.05
16		8	240432	234.657	0.98
17	12	5	180324	227.727	1.26
18		6	216388.8	245.485	1.13
19	16	5	240432	327.989	1.36

C. Load Carring Capacity of Both Side Alternate Stiffeners

The parameters considered for the diagonal stiffeners are thickness and width of the stiffener. For diagonal stiffener the thickness is 5mm, 6mm, 8mm, 10mm, 12mm and 16mm then according to Euro code the minimum provision of area As=30Ɛ tw where maximum area criteria for diagonal stiffener is considered to be equal of undisturbed strip area, which is 30% of the area of hollow opening. Hence, the according to it thickness x width combinations are made. Spacing for diagonal stiffeners is equal to S i.e. for hexagonal beam spacing = 225. All the stiffener sizes provided for the castellated beams are given in Table. These all diagonal stiffeners are modelled and analyzed in ABAQUS software and optimized section is found out.

Table No.8: Load Carring Capacity of Both Side Alternate Stiffeners

Sr No	Thickness	Width	Total Volume For 5	Load Carring Capacity	Ratio
1	5	10	150270	127.142	0.85
2		11	165297	128.795	0.78
3		12	180324	130.872	0.73
4		13	195351	132.654	0.68
5		14	210378	138.456	0.66
6		15	225405	140.134	0.62
7		16	240432	141.224	0.59
8	6	10	180324	134.896	0.75
9		11	198356.4	137.128	0.69
10		12	216388.8	139.865	0.65
11		13	234421.2	142.076	0.61
12	8	10	240432	154.419	0.64
13	10	5	150270	148.626	0.99
14		6	180324	154.638	0.86
15		7	210378	160.967	0.77
16		8	240432	167.31	0.70
17	12	5	180324	167.575	0.93
18		6	216388.8	175.978	0.81
19	16	5	240432	213.866	0.89

D. Result For Cross Stiffener Connect inside the Opening Not Overlap Each other

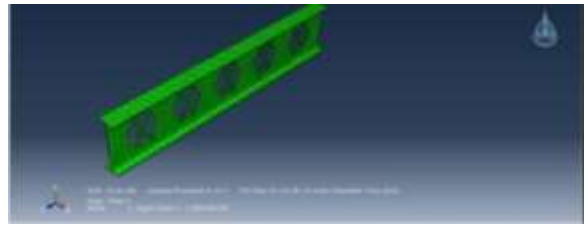

Figure No. 9: Load Carrying Capacity

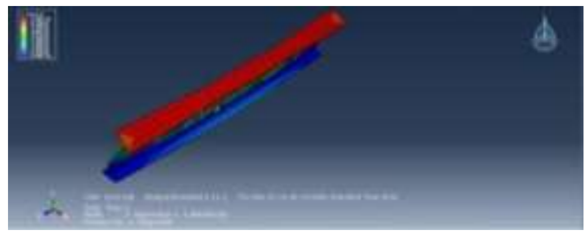

Figure No. 10: Failure of Cross Stiffener Connect inside the Opening Not Overlap Each other: Mode 1

VI. CONCLUSION

The optimization of the design for the proper combination of stiffener with castellated beam is not yet completed. Though codal provisions provide design of opening sizes but yet data related to stiffener is not satisfactorily incorporated in the provisions. In this chapter all past literature is up till now on castellated beam and its performance under flexure. Stiffeners are compared to beam with and without stiffeners but yet the proper design specification for stiffeners is not included in any of Indian codes.

The axial strengths found in ABAQUS are compare with Cross Stiffener Connect inside the Opening Not Overlap Each other & stiffener connecting outside the opening of both side and alternative; it is observed that result of stiffener connecting outside the opening of both side is more as compare to result of stiffener connecting outside the opening of alternative & Cross Stiffener Connect inside the Opening Not Overlap Each other.

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